# Weeds

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# *Weeds*

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# Table of Contents


| | Page |
|---|---|
| Oxalate and Mineral Contents of *Halogeton glomeratus*. Howard L. Morton, Robert H. Haas, and Lambert C. Erickson | 255 |
| Weeds in Alaska and Some Aspects of their Control. C. H. Dearborn | 265 |
| Amino Triazole for Control of Redroot in Cranberries. W. F. Meggitt and R. J. Aldrich | 271 |
| Effect of Amitrol Sprays on the Growth and Development of the Cranberry. Malcolm N. Dana | 277 |
| Residual Herbicidal Activity of Some Chloro-Substituted Benzoic Acids in Soil. W. M. Phillips | 284 |
| The Translocation of 2,4–D–1–$C^{14}$ in *Potamogeton pectinatus*, a Submersed Aquatic Plant. F. D. Aldrich and N. E. Otto | 295 |
| The Absorption and Translocation of $C^{14}$-Labeled Simazin by Corn, Cotton, and Cucumber. D. E. Davis, H. H. Funderburk, Jr., and N. G. Sansing | 300 |
| Control of Certain Aquatic Weeds in Missouri Farm Ponds. Charles R. Walker | 310 |
| Chemical Weed Control in Seedling Alfalfa. II. Control of Broad-leaved Weeds. Paul F. Sand and M. K. McCarty | 317 |
| Logarithmic Sprayer Evaluations of Herbicides in Horticultural Crops. L. L. Danielson and Robert E. Wester | 324 |
| Effects of DCB, DCB-xylene Mixtures, Amitrol, and Sodium Salt of Dalapon in Irrigation Water on Corn and Rutabagas. V. F. Bruns and J. H. Dawson | 333 |
| A Three-year Study of the Effect of Some Phenoxy Herbicides on Cotton. W. K. Porter, Jr., C. H. Thomas, and J. B. Baker | 341 |
| Substituted Urea Herbicides: Their Electrophoretic Behavior and the Influence of Clay Colloid in Nutrient Solution on Their Phytotoxicity. C. W. Coggins, Jr. and A. S. Crafts | 349 |
| Brief Papers | |
| The Effect of Temperature and Light on Germination of Seed of Goosegrass, *Eleusine indica*. J. R. Fulwider and R. E. Engel | 359 |
| The Persistence of 4–(2–methyl–4–chlorophenoxy)butyric acid in Peas. H. A. Glastonbury, Margaret D. Stevenson, and R. W. E. Ball | 362 |
| Spectrofluorometric Determination of 1,1′–Ethylene 2,2′–bipyridylium Dibromide (FB/2). V. H. Freed and Robert E. Hughes, Jr | 364 |
| Sustaining Members | 365 |
| News and Notes | 366 |
| Bibliography of Weed Investigations, October to December, 1958 | 367 |


# Advertisers Index


| | |
|---|---|
| duPont de Nemours & Co. | ii |
| U. S. Borax & Chemical Co. | iii |
| Stauffer Chemical Co. | iv |
| Chipman Chemical Co. | v |
| Spraying Systems Co. | vi |
| Union Carbide Chemicals Co. | vii |

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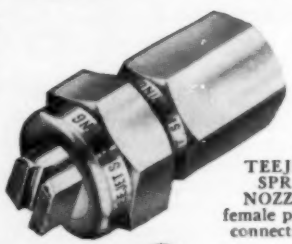

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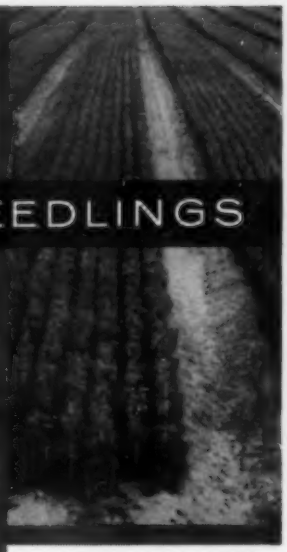

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Weeds

JOURNAL OF THE WEED SOCIETY OF AMERICA

VOLUME 7 JULY 1959 NUMBER 3

# Oxalate and Mineral Contents of *Halogeton Glomeratus*[1]

HOWARD L. MORTON,[2] ROBERT H. HAAS,[3] and LAMBERT C. ERICKSON[4]

OXALIC acid and oxalates occur in many plants. Consumption of plants containing high concentration of oxalates can be poisonous to animals. This has been reported by several investigators (5, 7, 9). However, in only a few plants are oxalates found in sufficient quantities to be lethal. Some species with a relatively high oxalate content are: sorrel (*Rumex* spp.), rhubarb (*Rheum* spp.), greasewood (*Sarcobatus vermiculatus* Torr.), soursobs (*Oxalis cernus* Thunb.), and halogeton (*Halogeton glomeratus* C. A. Mey.).

Early literature makes no reference to the occurrence of oxalate in halogeton or of its possible poisonous effects upon animals. Following severe livestock losses in 1942, investigators at the University of Nevada Agricultural Experiment Station found large quantities of halogeton in the stomachs of poisoned animals. They (6) later found that halogeton contained oxalates equivalent to as high as 19 percent anhydrous oxalic acid and suggested oxalate as the toxic principle in halogeton. Their work showed also that the amount of halogeton required to kill a sheep was approximately 166 grams per 100 pounds of body weight (4). Studies in Utah (2) determined that 12 ounces or 342 grams of halogeton containing 8.7 percent soluble oxalates, or about 1 ounce of the soluble oxalates, were required to kill a sheep. This occurred after fasting sheep for 36 hours and giving the halogeton in a single feeding. However, 18 ounces of halogeton, equivalent to 1.6 ounces of the soluble oxalates, were required to produce lethal effects when the animal had been maintained on its usual ration.

Livestock losses due to halogeton poisoning have generally occurred during the fall and early winter, but some losses have

[1]Cooperative investigations of the Idaho Agricultural Experiment Station and the Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture. Published with the approval of the Director of the Idaho Agricultural Experiment Station as Research Paper No. 447.

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occurred during the spring. Historically these losses have been sporadic and severe.

Dye (3) found that the leaf-seed-sepal fraction of the halogeton plant contained most of the soluble oxalate (19.53 to 32.81 percent) and that the stem fraction contained relatively small amounts (1.59 to 5.06 percent). He also found that the leaf-seed-sepal fraction collected in August contained 17.98 percent crude protein, 5.51 percent ether extract, 12.67 percent crude fiber, 22.25 percent nitrogen-free extract, and 41.59 percent ash; and that the stem fraction contained 7.83, 0.83, 29.32, 34.48, and 27.54 percent of these constituents, respectively. Cook and Stoddart (2) reported that halogeton plants contained up to 28 percent soluble oxalates during the early fall and decreased to a minimum of 5 percent by early spring, except in instances where the plants were covered with snow during the winter months.

Prior to 1950, only meager information was available concerning the accumulation and persistence of oxalate in halogeton plants throughout the entire year. Information on chemical constituents other than oxalates was lacking. No data were available concerning the composition of halogeton plants growing on soils in southern Idaho, where some of the major livestock losses have occurred.

The present investigations were initiated in southern Idaho in 1950 to determine the variations and trends in the chemical composition of halogeton as influenced by growth stages, weather conditions and soil types. Chemical analyses were made on samples collected at intervals throughout the year from several locations to determine seasonal variations in: (1) water-soluble and total oxalate content; (2) rate of oxalate loss under observed weather conditions; (3) oxalate and cation contents of plants grown in soils of varying soil salinity; and (4) ash content.

## MATERIALS AND METHODS

*Oxalate studies.*

Two types of studies were conducted to determine the quantity of oxalates in halogeton and factors influencing concentration and persistence. The first was initiated in 1950 and continued as a combined study for three successive years. This study was designed to determine the oxalate content throughout the entire year, beginning with the young growth in June and continuing through to the following April. Collections were made in three sampling areas in the Raft River Valley of southern Idaho. These were progressively about 20 miles apart, namely, at the Idahome, Bridge, and Almo desert exclosures, all in Cassia County.

To obtain more detailed information on the influence of environmental site a second study was initiated in 1951. In it the analyses from the three sites were calculated and maintained separately. This study demonstrated the influence of environment on plant growth and subsequent oxalate persistence.

Typically the plants mature in September but they maintain their

same stiff upright position into the succeeding spring. In this study as in all succeeding phases the samples were obtained by severing the plants at the soil surface. They were weighed immediately, air dried, and stored for further analyses. Oxalate determinations were made by the method developed by Miller (6) and described by Dye (3).

A third study to determine influence of precipitation on oxalate loss in halogeton was initiated in the fall of 1951. Plants were obtained from a localized area near Idahome in mid-September. The plants were selected for uniformity of development and size. Twenty plants were protected indoors until November 3 when they were secured in a firm upright position in wooden flats and placed in the fenced weather station exclosure on the University of Idaho campus at Moscow.

*Oxalate and cation studies.*

To obtain more detailed information on chemical composition two additional studies were conducted. In the first, halogeton samples were collected at Bridge during the 1951 growing season. These were analyzed for the following constituents: water-soluble and total oxalates, and total sodium, potassium, calcium, and magnesium.

Still more detailed information on environmental influence upon chemical composition was derived from a vegetation type study. Plants were collected in September 1956 from sites representative of the sagebrush *(Artemisia tridentata* Nutt.), salt sage *(Atriplex Nuttallii* S. Wats.), and perennial Kochia *(Kochia vestita* S. Wats.) vegetational types and subjected to similar analyses. In addition, a collection was made from a site denuded of all perennial vegetation. Like many small desert sites this area had the perennial vegetation so completely removed that it was impossible to determine its original vegetal cover. This area is hereafter designated as the bare site.

Soil profile samples were taken from each of the mentioned collection sites. These were analyzed for pH of the soil paste; electrical conductivity; total, exchangeable, and water-soluble sodium; and for water-soluble potassium, calcium, and magnesium.

Analyses for total sodium and potassium in the plants were run according to flame photometric procedures. Total calcium and magnesium were determined by analyzing for the oxalate and phosphate precipitates of these ions respectively. Cations were determined as percent of air-dry plant materials. Soil and plant analyses were conducted as outlined in Agricultural Handbook No. 60 (8) and the Official Methods of Analysis of the Association of Official Agricultural Chemists (1).

Three major collections were used for ash determinations: (a) the 1951–52 collections; (b) plants collected at four stages of growth at Bridge, during the 1951 growing season; and (c) plants collected from the four vegetation types in September 1956. The ash determinations were made using a muffle furnace at a dull red heat until the samples were burned to a whitish-tan color. All determinations were made on air-dry plant materials.

## RESULTS AND DISCUSSION

*Influence of season and location on oxalate content.*

Data on both the water soluble and the total oxalate contents of halogeton plants collected during 1950, 1951, and 1952 are contained in Table 1. These are expressed as the percentage of air-dry weight

*Table 1.* Average percentages of water-soluble and total oxalate content (air-dry basis) of halogeton plants collected at the Idahome, Bridge, and Almo exclosures during the 1950, 1951, and 1952 growing seasons and in the subsequent fall, winter, and spring months.

| Collection month | Growth stage or condition | Average percent oxalate in halogeton | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1950–51 | | 1951–52 | | 1952–53 | | 3-year average | |
| | | Water-soluble | Total | Water-soluble | Total | Water-soluble | Total | Water-soluble | Total |
| June | Cruciform | 19.3 | 21.6 | 17.9 | 21.2 | 19.5 | 20.6 | 18.9 | 21.1 |
| July | Mid-flowering | 18.5 | 20.9 | 16.6 | 19.6 | 17.5 | 19.1 | 17.5 | 19.9 |
| August | Late flowering | 16.3 | 19.1 | 15.2 | 17.5 | 15.5 | 17.6 | 15.7 | 18.1 |
| September | Seed maturation | 18.1 | 20.6 | 15.5 | 17.5 | 16.7 | 17.8 | 16.8 | 18.6 |
| November | Dead | 14.9 | 20.6 | 14.9 | 16.4 | 16.2 | 16.5 | 15.3 | 17.8 |
| December | Dead | 8.9 | 11.9 | 16.7 | 17.0 | 15.6 | 17.4 | 13.7 | 15.4 |
| January | Slightly weathered | 6.5 | 9.7 | —— | —— | 12.6 | 16.4 | 9.6 | 13.1 |
| February | Weathered | 5.6 | 9.5 | 10.2 | 13.6 | 7.5 | 10.4 | 7.8 | 11.2 |
| March | Extremely weathered | 3.9 | 8.7 | 6.5 | 9.1 | —— | —— | 5.2 | 8.9 |
| April | Extremely weathered | 2.1 | 6.3 | 7.6 | 10.6 | —— | —— | 4.8 | 8.4 |

equivalent to anhydrous oxalic acid. The oxalate concentration was found to be consistently high throughout the growing season. It was usually highest in June, tending to decrease during July and August, with a slight increase occurring in September. Thereafter the oxalate content decreased progressively into spring.

As shown in Table 2, the rate of oxalate loss in 1951–52 was different at each of the three collection sites. Presumably this was due to differences in the size and growth habits of the plants and differences in the amount and type of precipitation. In these collections the plants at Idahome were tall and upright, those at Almo of intermediate growth, and those at Bridge short and prostrate. The September collections contained 18.7, 16.4, and 17.4 percent total oxalates respectively. By the following April few leaves remained on the tall Idahome plants while the short Bridge site plants retained

*Table 2.* Average percentage of water-soluble and total oxalate content (air-dry basis) of halogeton plants collected at the Idahome, Bridge, and Almo exclosures during the fall, winter, and spring months of 1951–1952.

| Collection month | Percent oxalate in halogeton | | | | | |
|---|---|---|---|---|---|---|
| | Idahome | | Bridge | | Almo | |
| | Water-soluble | Total | Water-soluble | Total | Water-soluble | Total |
| September | 16.6 | 18.7 | 15.1 | 17.4 | 14.8 | 16.4 |
| November | 15.1 | 17.9 | 16.7 | 18.4 | 14.7 | 15.0 |
| December | 8.7 | 11.3 | 16.7 | 17.8 | 22.9 | 23.6 |
| February | 6.0 | 8.8 | 9.8 | 14.3 | 14.7 | 17.6 |
| March | 2.8 | 3.5 | 7.1 | 13.9 | 9.7 | 9.9 |
| April | 5.6 | 5.9 | 10.0 | 14.5 | 7.2 | 11.4 |

most of theirs. The April 1952 collections yielded 5.9, 11.4, and 14.5 percent total oxalates for the Idahome, Almo, and Bridge samples respectively.

In the October collections a portion of the plants from the Idahome site were divided into stem, and leaf-seed-sepal fractions. These were found to have a total oxalate content of 2.0 percent in the stems and 24.6 percent in the leaf-seed-sepal fraction. These results confirm Dye's (3) report that most of the oxalate is contained in the leaf-seed-sepal fraction.

Since most of the oxalates occur in the leaf fraction, loss of leaves, seeds, and sepals probably accounts for the major differences in oxalate content among different sites as the seasons advanced. Therefore, high leaf retention at a certain site may account for livestock losses in early spring even though the mature halogeton has been assumed to have a uniformly low oxalate content. Likewise, the toxicity revealed in feeding trials may vary primarily according to the proportion of leaves present in the samples fed.

Halogeton is a very succulent plant containing as high as 85 percent moisture early in the growing season. A high moisture content is retained throughout the growing season, dropping to a minimum of 50 percent in September. The data show that young and mature plants contain practically equal concentrations of oxalates on a dry weight basis. However, the high moisture content of green halogeton may in part explain why no livestock losses have been reported during the summer. Due to the high moisture content of green plants a much greater volume would have to be consumed during the summer than in the winter to obtain equivalent amounts of oxalate. In addition, it appears that halogeton is relatively less palatable during the summer, and also, other forage plants are usually more abundant than in the fall and winter.

*Rate of oxalate loss.*

The percentage oxalate in halogeton plants exposed to weather conditions from November 3, 1951, to April 28, 1952, under the humid conditions at Moscow, Idaho, are shown in Table 3. From November 3 to December 1, 1951, relatively little precipitation occurred until the last two days of this interval. This precipitation was sufficient to thoroughly wet the plants. During the period December 1 to December 3 nearly all of the precipitation occurred in the form of rain and resulted in the largest oxalate loss per unit of precipitation during the study. From December 3 to December 20 precipitation occurred as both rain and snow but produced less oxalate loss per inch of precipitation than in the preceding interval. From December 20, 1951, to January 27, 1952, most of the precipitation was in the form of snow. Although precipitation during this interval totaled 4.5 inches, the decrease in total oxalate in the halogeton plants was only 0.6 percent per inch of precipitation. However, from January 27 to February 28, 1952, most of the precipitation occurred as rain. In this instance, the decrease in total oxalate was 1.9 percent per inch of precipitation. In the study of

oxalate contents in the field (Table 2) and in this study at Moscow snow appeared to be less effective than rain in reducing the oxalate content.

*Table 3.* Average content of halogeton plants (calculated on air-dry basis) exposed to weather conditions at Moscow, Idaho, from November 3, 1951, to April 28, 1952.

| Sampling date | Precipitation between sampling dates | | Oxalate content, percent | | Percent of initial oxalate lost[a] | | Oxalate loss/inch of precipitation, percent | |
|---|---|---|---|---|---|---|---|---|
| | Total inches | Snow inches | Water-soluble | Total | Water-soluble | Total | Water-soluble | Total |
| November 3, 1951 | | | 14.0 | 15.5 | | | | |
| December 1, 1951 | 1.7 | 0.0 | 11.8 | 13.7 | 15.7 | 11.6 | 1.3 | 1.1 |
| December 3, 1951 | 0.4 | Tr. | 10.0 | 11.4 | 28.6 | 26.4 | 4.5 | 5.8 |
| December 20, 1951 | 1.4 | 9.3 | 8.0 | 10.6 | 42.8 | 31.6 | 1.4 | 0.6 |
| January 27, 1952 | 4.5 | 45.7 | 6.5 | 7.8 | 53.6 | 49.7 | 0.3 | 0.6 |
| February 28, 1952 | 1.8 | 6.0 | 3.1 | 4.4 | 77.8 | 71.6 | 1.9 | 1.9 |
| March 20, 1952 | 1.2 | 4.0 | 0.5 | 0.7 | 96.4 | 95.5 | 2.2 | 3.1 |
| April 28, 1952 | 2.0 | 0.0 | 0.2 | 0.4 | 98.6 | 97.4 | 0.2 | 0.2 |
| Total | 13.0 | 65.0 | | | | | | |

[a]Values calculated from initial water-soluble and total oxalate contents of 14.0 and 15.5 percent, respectively.

These studies demonstrated that the reduction of oxalate in halogeton is due primarily to leaf and seed drop expedited by precipitation. Since in October collections the combined leaves, seeds, and fruiting bracts contain about 12 times as much oxalate as the stems, the loss of these parts has a much greater effect upon the decrease in oxalate contents than the leaching of plants. The type of precipitation can be an important factor in the rate of oxalate loss, since heavy sleet or violent wind storm may contribute to leaf fall. Furthermore, the storms occurring in the halogeton-infested areas of the western United States are often localized. This can cause considerable variation in the rate of decline in oxalate contents in different localities. For example, when the plants are covered with snow during much of the winter, the plants may maintain a high oxalate concentration into early spring. This combined with the typical scarcity of late-winter forage increases the hazard of late-winter or early-spring poisoning. Conversely, precipitation in the form of rain and an open winter may decrease the hazard of livestock poisoning.

*Interrelation of oxalate and cation contents and soil type.*

Table 4 shows the oxalate and cation contents of halogeton plants collected at Bridge at several growth stages in 1951. Both the oxalate and sodium contents decreased from the early stages of growth through the mid-flowering stage. The potassium, calcium, and magnesium levels remained relatively constant. Samples collected at the seed maturation stage contained slightly greater amounts of oxalate and sodium than samples collected at the late-flowering stage. The sodium content was relatively high at all stages of growth.

*Table 4.* Average percentage of oxalate and cation content (calculated on air-dry basis) of halogeton plants collected at Bridge, Idaho, at four stages of growth in 1951.

| Date | Growth stage | Oxalate content, percent | | Cation contents, percent | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Water-soluble | Total | Na | K | Ca | Mg | Total |
| June 22 | Cruciform | 21.4 | 24.3 | 11.3 | 3.8 | 1.4 | 0.6 | 17.1 |
| July 23 | Mid-flowering | 18.6 | 21.2 | 10.0 | 3.7 | 1.2 | 0.5 | 16.4 |
| August 22 | Late flowering | 17.1 | 19.2 | 9.3 | 3.9 | 1.3 | 0.5 | 15.0 |
| September 21 | Seed maturation | 17.8 | 20.2 | 9.7 | 3.9 | 1.3 | 0.4 | 15.3 |

The oxalate and cation contents of plants collected from the four vegetation-type sites are shown in Tables 5. The sodium content was found to be extremely high in plants grown at all the sites, ranging from 8.0 percent at the sagebrush vegetational type to 12.5

*Table 5.* Average oxalate and cation content (calculated on air-dry basis) of halogeton plants collected in September 1956, from four vegetational types in southern Idaho.

| Vegetational type | Oxalate content, percent | | Cation content, percent | | | | |
|---|---|---|---|---|---|---|---|
| | Water-soluble | Total | Na | K | Ca | Mg | Total |
| Bare[a] | 16.8 | 18.3 | 11.9 | 3.0 | 0.6 | 0.4 | 15.9 |
| Saltsage | 18.0 | 19.4 | 10.4 | 4.1 | 0.8 | 0.5 | 15.8 |
| Kochia | 18.5 | 20.2 | 12.5 | 3.8 | 0.7 | 0.4 | 17.4 |
| Sagebrush | 14.8 | 17.5 | 8.0 | 5.0 | 1.3 | 0.7 | 15.0 |

[a]A site without perennial vegetation covered primarily with clasping-leaved peppergrass (*Lepidium perfoliatum* L.), halogeton, and other annuals.

percent at the kochia type. There appeared to be an inverse relationship between sodium and the other cations. The percentages of potassium, calcium, and magnesium from the different sites were greater in plants containing less sodium. Oxalates were found to be higher in plants containing the greatest percentage of sodium and the least percentage of other cations. Larger quantities of insoluble oxalates (differences between the total and water-soluble oxalates) were found in plants containing the greater quantities of calcium. These relations suggest that the oxalate content of halogeton may be associated with the mineral composition of the plant.

Soil analyses from the four vegetative-type sites appear in Table 6. The sample depth; pH; electrical conductivity; total, exchangeable, and water-soluble sodium; and other water-soluble cations are given. Samples from the entire soil profile at each site were analyzed; however, portions of the soil profile from approximately 4 to 13 inches were found to characterize the soil profiles. For the sake of brevity, only data from this portion of each soil profile are presented (Table 6). From these data it is evident that halogeton occurs under widely varying soil conditions and can grow on soils of very high salinity. It is also apparent that the concentration of cations in halogeton is not directly correlated to their relative concentration in the soil.

The large quantities of sodium found in plants grown on soils of both high and low sodium concentrations indicate that this plant is an accumulator of sodium.

The data suggest that with increasing soil pH there was a decrease in accumulation of sodium in the plants. Plants growing in soils with pH readings of 7.7, 7.9, 8.1, and 8.2 (Table 6) had sodium percentages (Table 5) of 12.5, 11.9, 10.4, and 8.0, respectively. The high sodium content in the soils of low pH readings undoubtedly influenced the accumulation of this ion in the plants; however, the plants did not accumulate sodium in proportion to the concentration of sodium in the soil.

*Table 6.* Cation content, electrical conductivity, and pH of soils collected in September, 1956, from four vegetational types in southern Idaho.

| Vegetational type | Sample depth inches | Electrical conductivity ($ECX10^3$)[b] | pH[c] | Cations = milliequivalents per 100 grams of soil | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Total Na | Exchangeable Na | Water-soluble cations | | | |
| | | | | | | Na | K | Ca | Mg |
| Bare[a] | 5–10 | 62.3 | 7.9 | 29.2 | 8.5 | 20.7 | 0.6 | 2.4 | 0.9 |
| Saltsage | 4–12 | 2.2 | 8.1 | 1.0 | 0.8 | 0.2 | 2.4 | 0.2 | 0.1 |
| Kochia | 6–12 | 45.3 | 7.7 | 21.9 | 5.8 | 16.1 | 0.7 | 3.4 | 1.6 |
| Sagebrush | 6–13 | 1.1 | 8.2 | 1.0 | 0.9 | 0.1 | 0.3 | 0.2 | 0.1 |

[a]A site without perennial vegetation covered primarily with clasping-leaved peppergrass (*Lepidium perfoliatum* L.), halogeton, and other annuals.
[b]Electrical conductivity is millimhos/cm ($ECX10^3$) at 25° C. of a saturated soil extract.
[c]pH determined on saturated soil paste.

### *Ash contents*

Data on the ash contents of halogeton plants collected during the 1951 growing season and the fall, winter, and spring of 1951–52 are summarized in Table 7. The ash content was highest in June, when the plants were growing most rapidly, and lowest the following April. The ash content was found to be extremely high during the growing season.

The samples collected during the growing season fused when ashed at temperatures above 750° F. The fusion temperature progressively increased for the samples collected during the following fall, winter, and spring. This would indicate that the lighter metals were lost as the plants weathered.

The ash contents of plants collected in 1951 at Bridge in the cruciform, mid-flowering, late flowering, and seed maturation stages were 36.7, 35.2, 34.2, and 33.9 percent, respectively. These values are somewhat lower than those given in Table 7 for the samples

*Table 7.* Average ash content of halogeton plants collected from three sites during the 1951 growing season and the fall, winter, and spring of 1951–52, calculated on basis of air-dry plant material.

| Collection month | Ash content % | Collection month | Ash content % | Collection month | Ash content % |
|---|---|---|---|---|---|
| June 1951 | 40.2 | September 1951 | 35.3 | February 1952 | 22.0 |
| July 1951 | 37.7 | November 1951 | 32.2 | March 1952 | 21.2 |
| August 1951 | 37.9 | December 1951 | 25.6 | April 1952 | 20.8 |

collected from June to September at other sites, but they show the same progressive decrease in ash content as the plants advance in maturity.

In addition to the elements listed in Tables 4 and 5, qualitative analyses of the ash revealed the presence of many other elements commonly found in plants. Quantitative analyses failed to show a large accumulation of other elements.

The halogeton plants collected from the kochia, bare, saltsage and sagebrush vegetational type sites (Table 6) contained 39.9, 39.5, 34.1 and 33.2 percent ash, respectively. These data suggest that with increasing soil pH there was a decrease in accumulation of total ash in the plants. This is probably due to the influence of pH upon the sodium accumulation in the plants.

The accumulation of large amounts of ash from throughout its root zone and especially large amounts of sodium suggests that the annually returning plant residues may increase salinity of the surface soil. While this may be only of minor importance in areas supporting the salt-desert shrub vegetational types, it could be of major importance in the sagebrush-grass and other types with non-saline soils in converting these to a saline-alkali type.

## SUMMARY

The oxalate and mineral contents of halogeton plant material were studied by collecting plants at monthly intervals during three growing seasons and the subsequent fall, winter, and spring. Rate of oxalate loss from halogeton plants exposed to weather conditions at Moscow, Idaho, were determined. The oxalate and cation contents of halogeton plants were determined from collections made at different stages of growth and on various soil sites. It was found that:

1. The oxalate content of halogeton plants ranges from 18 to 21 percent on the air-dry weight basis, being highest in the early growing season when the plants are growing rapidly.
2. Most of the oxalate is contained in the leaves, seeds, and fruiting bracts, and relatively small amounts occur in the stems.
3. The rate of oxalate loss during the winter and spring months is affected more by factors which influence the loss of leaves, seeds, and fruiting bracts, than by total precipitation. However, rain appears to be more effective than snow in reducing the oxalate content of matured plants. These factors cause considerable differences in the oxalate contents of halogeton plants at different sites by late winter or early spring.
4. Halogeton plants accumulate large amounts of sodium. The sodium content is highest in young plants and declines steadily as the plants approach maturity. The content of potassium, calcium, and magnesium tends to vary inversely with the sodium content.
5. A relatively high oxalate concentration in the plants is associated with a high sodium content.
6. The ash content of halogeton is highest in young plants and

steadily declines during the growing season and the months following the plants maturity.

## ACKNOWLEDGMENTS

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# Weeds in Alaska and Some Aspects of Their Control

C. H. Dearborn[1]

Weed problems in Alaska are relatively new because man's agricultural activities in this region have been limited until very recently to isolated clearings. These early clearings made by prospectors and homesteaders to produce feed for their stock also unintentionally served as increase plots for some troublesome weeds.

Imported feeds to supplement locally produced forage brought weed seeds directly to the clearings as evidenced by stands of quackgrass now flourishing. Over the past decade homesteaders and earlier established farmers have cleared lands adjacent to some of the original clearings to increase production to meet the market demands of defense workers. As might be expected, these new clearings, coalescing with former weed patches, became quickly infested with quackgrass, lambsquarters, chickweed and mustard.

Natural agents such as strong winds, flash floods and animal life also aid in weed seed dissemination. Stump rows are a fertile haven for weeds. There they grow unnoticed and produce excellent seed crops for several years or until the stump row is finally burned and spread over the land by a bulldozer.

Alaskans today import practically all of their seeds of fruits, ornamentals and vegetables except potatoes. Seeds of grains, grasses and legumes are imported in considerable volume each year for feed and seed purposes. In addition, forage for dairies and peat moss for soil conditioning in greenhouses is received by these industries from the other States or Canada. Potted plants and nursery stock are still another avenue through which weed seeds are imported unintentionally. Little thought is given by either the customer or the supplier to the kind of weed seeds shipped into Alaska for bird feed. Within the past year, weeds new to a particular locality in Alaska were traced directly to commercial bird feeds imported from the States.

To illustrate further the need for concern about introducing weeds, barnyardgrass was introduced in carrot seeds in 1951. It is hoped that control measures applied in that year eliminated the weed, although not all plantings of carrots from this particular seed source could be checked. Perennial sowthistle was observed in 1951 and in 1953. Chemicals were used diligently to eradicate this weed but it has been observed several times since 1953 in the original area. Bladder campion was identified in 1957 in a new seeding of timothy. More recently it has been located in another area entirely independent of the above introduction.

Alaska's position is different from that of the other States in that many weed species that could be troublesome do not at present exist here. A partial list of agriculturally important weeds not now in Alaska is shown in Table 1. This list contains enough important

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weeds such as bindweed, foxtail, galinsoga, leafy spurge, nutgrass, ragweed and wild carrot to cause agriculturists considerable trouble. Furthermore, the introduction of a new weed species might serve as an additional host plant for some disease or insect pest not yet established here. Earlier reports (1) (4) of plant species in Alaska contain the names and locations of the following weeds: *Bidens cernua, Cirsium vulgare, Nepeta cataria, Malva neglecta, Verbascum thapsus, Setaria sp., Glechoma hederacea, Lactuca scariola, Amaranthus retroflexus, Tanacetum vulgare* and *Oxalis corniculata.* Although the records indicate that some of these species may not have been adapted, it must be realized that commercial agricultural areas were not open at the time and in the areas where these weeds were found.

## ECONOMIC ASPECTS

There is much concern now that seeds of weed species new to Alaska will be imported more frequently. Never before has the volume of imports of agricultural supplies approached its present level. The peak is far from being in sight. This expansion increases the probability of importing troublesome weed seeds. Crops are now being grown commercially that heretofore were planted only in the home garden. Where in earlier years most farming, as in the other States, was carried on by men reared in the business of farming, such is not the case in Alaska today. Thus the chances are far greater than in earlier years that a weed will mature seed without being recognized as a new menace to an area.

The average agricultural worker seldom, if ever, takes inventory of his weed population when he moves from one region to another except as he remembers which one or ones were the most troublesome. Consequently he may plant a weed seed in a new region and permit it to produce seeds because he has tolerated it before or because he does not realize it is new to the region.

Regulations governing the movement of seed imports to Alaska have been in effect only since 1945. Much effective inspection work has been carried on during this time against rather considerable odds. Possible avenues of import, coupled with the great distances between centers of distribution in Alaska, have handicapped regulatory work. Control measures effective in other States are difficult to apply to Alaska. For example, the movement between States of a sample of seeds containing a trace of weed seeds is permissible when both States have the same weed but not permissible when the weed is not present in a State. Some protection would be afforded by greater use of certified seeds. Additional precautions for Alaska seem desirable in view of the weeds that could be imported.

## WEED SPECIES NOW IN ALASKA

Only a few of the many weed species observed in Alaska are of economic importance. Table 2 lists those that have attracted attention. Of these, chickweed, lambsquarters, quackgrass, wild mustard, pineapple-weed and climbing buckwheat have been the greatest

nuisance. Shepherds purse, spurry, Pennsylvania smartweed, squirrel-tail barley, common sowthistle, pennycress, peppergrass, dead nettle and the several mustards listed have only recently attracted attention. With an expanding agriculture, their influence in the cropping system may cause farmers considerable additional expense. These weeds are not indigenous to Alaska. Fireweed, horsetail, northern Grass-of-Parnassus, water hemlock and aconite species are natives of the region. The first three weeds can be controlled by a well-planned cropping system.

Canada thistle, although present in several patches is being reduced each year thru the combined efforts of the land owners, the Alaska Department of Agriculture and the Experiment Station. Water hemlock and aconite species occur in swamps and open woodlands and have in very recent years accounted for rather heavy losses of stock. Control of these species is difficult because of their scattered occurrence.

Some persons might be comforted in presuming that the rather limited number of weeds troublesome to gardeners in Alaska is due to lack of adaptation of certain species. The absence of ragweed, which is considered (3) a short day plant, may be due to a failure of the floral parts to develop under the long photoperiod of these latitudes (60° to 64° N.) However, local experiences with cultivated crops and weeds indicate that there would be ample time in some areas for seed development after the long-day portion of the growing season had passed.

Establishment and dissemination of nutgrass, Canada thistle, devils paintbrush, perennial sowthistle and others with subterranean storage organs might not be materially affected by photoperiod, because the existence in Alaska thus far of two of these species has not been dependent upon maturation of seeds. The seriousness of allowing weeds with fleshy storage organs to get established is illustrated by the persistence of horsetail. A stoloniferous smartweed infestation of a potato field in the Tanana Valley near Fairbanks illustrates the point quite well. This weed does not appear to have been reported previously in Alaska. It may have been indigenous to that area as no sexual reproductive structures were observed.

## INFLUENCE OF CULTURAL PRACTICES

In this environment climbing buckwheat, knotweed, Pennsylvania smartweed, spurry and pineapple-weed are typical examples of weeds that are spreading because of new cultural practices. Since 1951 potato growers have effectively used a pre-emergence dinitro spray to control broad-leaved weeds in potatoes (2). Control of chickweed, lambsquarters, mustard, Shepherd's purse and other broad-leaved types has been by a pre-emergence broadcast spray of not less than 3.75 pounds of 4,6–dinitro–*o*–*sec*–butylphenol per acre. This is the bare minimum. For clean culture 5.25 pounds is effective. Climbing buckwheat has some tolerance for this compound and generally survives lighter rates.

Grain growers have a similar problem with this weed. At the present time it appears that the only reason for the persistence of climbing buckwheat in grain crops is a tendency on the part of the grower to be conservative with the chemical spray. This same reasoning applies to knotweed and smartweed in grains, although these weeds have not yet become widespread.

Spurry has emerged in potato and grain fields and continued its growth to maturity in spite of the usual chemical weed control measures. Under the present system of crop management spurry will be a potent source of trouble in the near future. Pineapple-weed has persisted in carrot fields after spraying with oils normally used for weeding carrots. This may imply a resistance to oil sprays.

Quackgrass is grown as an economical forage by some dairymen. This adds a major obstacle in controlling its spread. Some knowledge has been gained toward eliminating quackgrass with dalapon or amitrol. If successful, either treatment will be quite expensive in terms of quantity applied or time lost in the use of the land except for potatoes.

A good crop of potatoes can be grown in quackgrass infested soil within the year of treatment if a delapon spray is applied to lush quackgrass foliage at least two weeks before potato planting. At the rate of 10 pounds of active ingredient per acre quackgrass stolons, if extended at all, apparently do not have the energy to penetrate a healthy potato tuber or interfere with potato digging. Mats of quackgrass stolons turned down in plowing frequently still remain as a major obstacle in digging the new crop of tubers. This condition prevails because decomposition of organic matter is slow in these cold soils. General gardening and quackgrass control have not been compatible so far because most small seeded crops are retarded in their growth by quantities of dalapon that are effective in controlling the grass.

Table 1. — Partial list of agriculturally important weed species not now in Alaska

| | |
|---|---|
| Beggar-ticks | *Bidens frondosa* L. |
| Bindweed | *Convolvulus sp.* L. |
| Bitter nightshade | *Solanum dulcamara* L. |
| Burdock | *Arctium sp.* L. |
| Cocklebur | *Xanthium sp.* L. |
| Devils paintbrush | *Hieracium aurantiacum* L. |
| Galinsoga | *Galinsoga parviflora* Cav. |
| Ground cherry | *Physalis sp.* L. |
| Horsenettle | *Solanum carolinense* L. |
| King devil | *Hieracium floribundum* Wimm. & Garb. |
| Leafy spurge | *Euphorbia esula* L. |
| Milkweed | *Asclepias syriaca* L. |
| Nutgrass | *Cyperus esculentus* L. |
| Poison ivy | *Rhus radicans* L. |
| Purslane | *Portulaca oleracea* L. |

Ragweed ..... *Ambrosia sp.* L.
St. Johns-wort ..... *Hypericum perforatum* L.
White cockle ..... *Lychnis alba* Mill.
Wild carrot ..... *Daucus carota* L.
Wild chicory ..... *Cichorium intybus* L.
Wild garlic ..... *Allium vineale* L.
Wormwood ..... *Artemisia annua* L.

Table 2. — Weeds in Alaska affecting agriculture

Annual bluegrass ..... *Poa annua* L.
Ball mustard ..... *Neslia paniculata* L.
Bladder campion ..... *Silene cucubalus* Wibel
Canada thistle ..... *Cirsium arvense* L.
Chickweed ..... *Stellaria media* L.
Climbing buckwheat ..... *Polygonum convolvulus* L.
Common horsetail ..... *Equisetum arvense* L.
Common sowthistle ..... *Sonchus oleraceus* L.
Dandelion ..... *Taraxacum officinale* Weber
Dead nettle ..... *Lamium purpureum* L.
Fireweed ..... *Epilobium angustifolium* L.
Northern Grass-of-Parnassus ..... *Parnassia palustris* L.
Hedge mustard ..... *Sisymbrium officinale* L.
Strawberry blight ..... *Chenopodium capitatum* L.
Kamchatka aconite ..... *Aconitum maximum* Pall.
Knotweed ..... *Polygonum aviculare* L.
Lambsquarters ..... *Chenopodium album* L.
Larkspur ..... *Delphinium glaucum* Wats.
Major plantain ..... *Plantago major* L.
Pennsylvania smartweed ..... *Polygonum pennsylvanicum* L.
Pennycress ..... *Thlaspi arvense* L.
Peppergrass ..... *Lepidium densiflorum* Schrad.
Quackgrass ..... *Agropyron repens* L.
Seacoast Angelica ..... *Angelica lucida* L.
Shepherds purse ..... *Capsella bursa-pastoris* L.
Smartweed ..... Stoloniferous type — not identified
Spurry ..... *Spergula arvensis* L.
Stinging nettle ..... *Urtica dioica* L.
Tansy mustard ..... *Descurainia sophia* L.
Water hemlock ..... *Cicuta mackenziana* Raup.
Squirrel-tail barley ..... *Hordeum jubatum* L.
Pineapple-weed ..... *Matricaria suaveolens* Pursh.
Wild chive ..... *Allium schoenoprasum* L.
Wild mustard ..... *Brassica arvensis* L.
Wild oat ..... *Avena fatua* L.
Yellow toadflax ..... *Linaria vulgaris* L.
Yarrow ..... *Achillea millefolium* L.

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# Amitrol for Control of Redroot in Cranberries[1]

W. F. Meggitt[2] and R. J. Aldrich[3]

Since weeds in cranberry bogs cannot be successfully controlled by mechanical equipment, there has been considerable interest in chemical means of control. Among the chemicals that have been and are presently being used are iron sulfate, paradichlorobenzene, sodium chloride, sodium arsenate, sodium arsenite, copper sulfate, kerosene, and other herbicidal oils (2). All these chemicals have to be applied in relatively large quantities, which makes for a large per-acre cost of treatment and involves many problems inherent in the application of large quantities of materials. There is, then, considerable interest in a chemical which can be applied in relatively small quantities and which will provide satisfactory control of weeds in the bogs.

In addition to providing competition to the cranberry plants, weeds are a serious problem at harvest time especially since mechanical harvesters have been introduced. Weeds mat and tangle with the cranberry vines and thus impair the operation of stripping the berries from the vines with either hand scoop or mechanical harvester.

Redroot *(Lachnanthes tinctoria)*, a perennial stoloniferous plant, is a particularly troublesome weed in many New Jersey cranberry bogs (1). It is found in sandy and peaty shores and swamps from Florida to Massachusetts and is aggressive in artificial cranberry bogs. It has both rhizomes and long slender stolons with a red juice, which prompts the name redroot.

Investigations were started in New Jersey in 1953 to evaluate certain of the newer herbicides for selectively eliminating this weed pest from cranberry bogs.

## Materials and Methods

In 1953 and 1954 several herbicides, isopropyl N–(3–chlorophenyl)carbamate (CIPC), 3–(p–chlorophenyl)–1,1–dimethylurea (monuron), 3–phenyl–1,1–dimethylurea (fenuron), maleic hydrazide, herbicidal oils, 3–amino–1,2,4–triazole (amitrol), and sodium 2,2–dichloropropionate (dalapon) were evaluated for their effectiveness in selectively removing redroot from cranberry bogs. These studies showed amitrol to be the only promising herbicide of those tested.

The preliminary work in 1953 and 1954 suggested that 2 pounds active ingredient per acre of amitrol was the approximate rate cranberries would tolerate even though in some tests higher rates have

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been used without reduction in yield. Other workers have also shown that cranberries are tolerant of amitrol at low rates (3, 4, 5).

On May 12, 1954, 1, 2, and 4 pounds per acre of amitrol were applied to 6- by 10-foot plots laid out in a bog uniformly infested with redroot. These treatments were made when the redroot plants were very small seedlings, 3–5 inches, and the cranberry vines had attained approximately 2 inches of growth from terminal buds. The amitrol was applied in 40 gallons of water per acre. Redroot counts of two 1-square-foot areas from each plot were made on September 2. Cranberries were gathered for yield determinations by hand-scooping the entire plot on September 2. The plots treated with 1 and 4 pounds of amitrol were also harvested in 1955.

On June 6, 1955, amitrol was applied at the rate of 1 and 2 pounds per acre to plots, 5 by 10 feet, in a randomized block design with 4 replications. Additional plots were included in the design to provide for retreatment in the fall, September 1. The redroot was 4 to 8 inches tall and cranberries showed considerable growth at the time of the June treatment. Yields were obtained on the entire plot in 1955, 1956, and 1957, and counts of redroot plants were made in 1957, the second year after treatment.

An experiment was conducted in 1956 to evaluate the rate and time of amitrol application, and to further evaluate the combination spring and fall treatment and fall treatment alone. One and 2 pounds per acre of amitrol were applied in the spring at three stages of growth of redroot: just emerged, 2–4 inches tall, and 5–8 inches tall. These applications were made at weekly intervals beginning on May 29. The plots were 5½ by 10 feet in a split-plot design with 4 replications, which allowed all combinations of the spring treatments with 1 pound of amitrol applied on September 13. Yields from the plots were taken on September 1, 1956, and on September 9, 1957. Counts of redroot plants were made on July 2, 1957.

All treatments in all years were made with a knapsack-type sprayer using a three-nozzle boom. The pressure was maintained at 30 psi as indicated by a pressure gauge mounted on the sprayer. The variety of cranberry used in these studies was Early Black.

## RESULTS AND DISCUSSION

The stand of redroot and yield of cranberries for amitrol treatments made in 1954 are shown in Table 1. All rates of amitrol

*Table 1.* The effect of amitrol applied May 12, 1954 on stand of redroot and cranberry yields. Whitesbog, New Jersey, 1955.

| Amitrol, lb/A | Redroot, plants/sq ft September 2, 1954 | Yield, lb/plot | |
|---|---|---|---|
| | | 1954 | 1955 |
| 0 | 33 | 3.9 | 4.7 |
| 1 | 18 | 4.4 | 5.1 |
| 2 | 19 | 2.5 | — |
| 4 | 10 | 0.6 | 0.8 |
| LSD 5% | | 2.1 | |

reduced the stand of redroot. The counts do not show the maximum effective control because many of the redroot plants present at the time the count was made probably emerged after the applications of amitrol. Those plants that were present in the treated plots were small and stunted in comparison to those in the untreated check plot.

Yields taken in 1954 and 1955 showed no reduction in cranberry yields from the 1-pound and 2-pound treatments but a significant reduction from the 4-pound treatment in the spring. Apparently cranberries have a certain tolerance for amitrol, but the tolerance range is quite narrow, especially for treatments made in the spring when plants are growing vigorously.

Although 4 pounds of amitrol significantly reduced the yield of cranberries in 1954 and 1955, the vines were not damaged. Observations in 1955 of those plots treated in 1954 indicated very effective redroot control with all rates of amitrol.

The data in Table 2 are the yields taken in 1955, 1956, and 1957 and redroot counts made in 1957 for those plots treated on June 6 and September 1, 1955.

*Table 2.* The effect of amitrol on control of redroot and on yields of cranberries treated in 1955. Whitesbog, New Jersey, 1957.

| Amitrol, lb/A | | Yield, lb/plot | | | Redroot count, plants/sq ft 1957 |
|---|---|---|---|---|---|
| June 6, 1955 | Sept. 1, 1955 | 1955 | 1956 | 1957 | |
| 1 | 0 | 10.2 | 4.4 | 6.4 | 22.7 |
| 2 | 0 | 8.6 | 4.9 | 5.7 | 19.4 |
| 1 | 1 | 10.0 | 4.1 | 6.4 | 2.8 |
| 1 | 2 | 9.3 | 5.2 | 7.4 | 2.5 |
| 2 | 1 | 10.2 | 5.6 | 7.4 | 1.8 |
| 2 | 2 | 11.1 | 3.9 | 6.9 | 2.4 |
| 0 | 0 | 10.2 | 3.8 | 6.4 | 27.1 |
| LSD | | N.S. | N.S. | N.S. | |

Control of redroot from treatments made only on June 6, 1955 was poorer than from the spring treatments in 1954, possibly because of the larger size of the redroot at the time of treatment in 1955 (3–5 inches in 1954 and 4–8 inches in 1955). One pound of amitrol applied on June 6 and September 1 resulted in complete control of redroot, as indicated by observations in 1956; and nearly complete control in 1957, as indicated by counts shown in Table 2. Any combination of a fall application of amitrol with a spring application resulted in nearly complete control of redroot. Counts made in 1957 showed poor carry-over control from the June 6 application, although counts were slightly lower than the check.

Yields taken in the three years, although variable from year to year, showed no significant reduction from 1 and 2 pounds of amitrol or combinations thereof in the spring and fall.

The effect of amitrol on the control of redroot and yield of cranberries treated in 1956 is shown in Table 3. Redroot was effectively controlled by all treatments in which 1 pound per acre was applied

in the fall immediately after harvest. It is evident from this experiment that treatments made only in the spring did not control redroot satisfactorily. One pound of amitrol applied in the fall was nearly as effective as the combination spring-fall treatment. The date of treatment in spring had little or no effect on control of redroot. However, counts for the treatment made only on June 5, and in combination with the fall application, were slightly lower than the other two dates of treatment in the spring.

*Table 3.* The effect of amitrol on control of redroot and yields of cranberries treated in 1956. Whitesbog, New Jersey, 1957.

| Amitrol, lb/A | | Yield, lb/plot | | Redroot, plants/sq ft |
|---|---|---|---|---|
| | | 1957 | 1956 | 1957 |
| May 29 | Sept. 13 | | | |
| 0 | 0 | 2.0 | 2.8 | 22.0 |
| 0 | 1 | 1.4 | — | 2.7 |
| 1 | 0 | 2.1 | 2.5 | 29.4 |
| 1 | 1 | 2.3 | — | 2.2 |
| 2 | 0 | 1.7 | 2.5 | 25.0 |
| 2 | 1 | 1.8 | — | 1.6 |
| June 5 | Sept. 13 | | | |
| 0 | 0 | 1.5 | 2.8 | 18.4 |
| 0 | 1 | 1.8 | — | 2.9 |
| 1 | 0 | 1.8 | 2.2 | 23.6 |
| 1 | 1 | 2.0 | — | 1.8 |
| 2 | 0 | 1.9 | 2.0 | 19.4 |
| 2 | 1 | 1.9 | — | 1.9 |
| June 12 | Sept. 13 | | | |
| 0 | 0 | 1.8 | 2.7 | 21.7 |
| 0 | 1 | 1.8 | — | 4.4 |
| 1 | 0 | 2.2 | 2.8 | 20.5 |
| 1 | 1 | 2.2 | — | 3.5 |
| 2 | 0 | 1.5 | 2.7 | 22.9 |
| 2 | 1 | 1.5 | — | 2.4 |
| LSD | | N.S. | N.S. | |
| Means for all dates in spring combined | | | | |
| 0 | 0 | 1.7 | 2.7 | 20.7 |
| 0 | 1 | 1.7 | — | 3.3 |
| 1 | 0 | 2.0 | 2.5 | 24.6 |
| 1 | 1 | 2.2 | — | 2.5 |
| 2 | 0 | 1.7 | 2.4 | 22.4 |
| 2 | 1 | 1.7 | — | 1.9 |
| LSD | | N.S. | N.S. | |

Yields in 1956 from plots treated on June 5 tended to be lower than on the other two dates. This difference was not statistically significant, but it approached significance at the 5 percent level. Yields from this experiment in 1957 were quite variable because of the variability of cranberry stand. None of the amitrol treatments reduced yields significantly in the year following treatment. The number of rotten and discard fruit was not influenced by treatment as counts of discard fruit were no greater from treated than untreated plots.

The effect on the control of redroot of 1 pound of amitrol applied as a post-harvest treatment on September 13 is shown in Figure 1.

*Figure 1.* Control of redroot with 1 pound of amitrol applied as a post-harvest treatment on September 13, 1956. Photo July 2, 1957. Left, check; right, 1 pound amitrol on September 13.

In general, it is logical to assume that amitrol may be somewhat damaging to cranberries, since the 4 pounds applied in the 1954 experiment caused a substantial reduction in yield. This indicates a rather narrow margin between the effective rate of 1 to 2 pounds and a rate which could damage the crop. One pound of amitrol applied immediately after harvest in the fall controls redroot satisfactorily with no injury or reduction in yield of cranberries.

The carry-over effect of controlling redroot for at least 2 years following the year of treatment indicates that control of redroot is a problem of eliminating the existing plants and not a problem of controlling seedlings which arise from seed.

Although yields were not increased in these experiments by removal of redroot it is felt that the increased ease of harvesting would justify control of this weed pest. Further the variability of the small plots employed may have masked any possible increase in yield due to removal of the redroot.

## SUMMARY

1. Several herbicides were evaluated for the control of redroot *(Lachnanthes tinctoria)* in cranberries. Of those investigated, amitrol was the only chemical which showed promise of selectively removing redroot from cranberries.

2. Rates and timing of application of amitrol were evaluated in 1955 and 1956.

3. Amitrol at 1 pound per acre applied in the fall immediately after harvest gave nearly complete control of redroot with no reduction in cranberry yield.

4. In general, spring applications of amitrol, at rates which would not damage cranberries, did not control redroot satisfactorily.

5. Control of redroot with amitrol was effective in the second and third year following treatment which indicates control is primarily a problem of eliminating existing plants and not a problem of controlling seedlings which arise from seed.

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# Effect of Amitrol Sprays on the Growth and Development of the Cranberry[1]

MALCOLM N. DANA[2]

THE cranberry *(Vaccinium macrocarpum)* is a low growing, perennial, woody plant of the boglands of the northern United States. Because cranberries are grown commercially on wet, low lying soils, the fields are often infested with a wide range of weeds common to such areas. Among the most common weeds of Wisconsin cranberry bogs are (1) sedge family: *Carex oligosperma, Dulichium arundinaceum,* and *Eriophorum virginicum;* (2) rush family: *Juncus effusus* and *J. canadensis;* (3) horsetail family: *Equisetum arvense* and *E. fluviatile;* (4) fern family: *Onoclea sensibilis* and *Osmunda regalis;* (5) water plantain family: *Sagittaria latifolia;* (6) grass family: *Leersia oryzoides, Glyceria canadensis* and *Calamagrostis canadensis;* (7) composite family: *Ambrosia artemisiifolia, Bidens connata,* and *Solidago graminifolia;* (8) primrose family: *Lysimachia terrestris* and *L. thyrsiflora;* (9) buckwheat family: *Polygonum sagittatum* and *P. amphibium;* (10) rose family: *Potentilla palustris* and *Rubus hispidus;* (11) mint family: *Lycopus uniflorus* and *Scutellaria epilobiifolia;* (12) St. Johnswort family: *Hypericum virginicum;* (13) gentian family: *Menyanthes trifoliata;* (14) willow family: *Salix nigra* and *Populus tremuloides.* Many other weed species occur in cranberry bogs, but they do not present a serious cultural problem.

Historically, weed control practices in cranberry bogs have been by hand weeding or by the application of either petroleum derivatives or certain inorganic salts. Standard practices were outlined by Cross (2) for Massachusetts and Dana (3) for Wisconsin. The recent development of the organic herbicides has opened up a new field of study for the control of the many weed pests.

Of the organic herbicides tested, 3–amino–1,2,4–triazole (amitrol) appears to offer the most promise for widespread use in cranberry bogs. Not only does it have a wide spectrum of weed species on which it is effective, but cranberries have exhibited a considerable tolerance to the effects of this material. Some of the weed species which have been found to be susceptible to control by amitrol are: common horsetail, *Equisetum arvense;* bugle weed, *Lycopus uniflorus;* star grass, *Dulichium arundinaceum;* wire grass, *Carex oligosperma;* and sickle grass, *Leersia oryzoides.* Aldrich (1) and Demoranville and Cross (5) have reported the effectiveness of this material on weed species in other cranberry growing areas.

Aldrich (1) reported that cranberry vines would tolerate 2 lb/A of the material without loss of crop when applied in June, but that 4 lb/A applied in May resulted in some crop reduction. Demoranville and Cross (6, 7) reported that cranberry vines would tolerate up

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to 12 lb/A of amitrol, but quantities in excess of 3 lb/A resulted in some crop reduction. Applications made in June resulted in the most pronounced reduction in crop yields. Dana (4) reported preliminary results which indicated that vines would tolerate 4 lb/A without undue injury.

These favorable reports from the use of this material emphasized the need for critical information about the effect of this herbicide on the growth and fruiting of the cranberry vine.

## METHODS AND MATERIALS

The experimental area selected was in an established cranberry bog section that was reasonably free of weeds. The variety of cranberry was Searles, a large fruited variety grown extensively in Wisconsin. The vines were in full production and promised a good crop in 1957. Bog management was according to accepted practice for most bogs in Wisconsin.

All herbicide applications were made with a bicycle-type plot sprayer calibrated to deliver 40 gallons of water per acre. Rates of application, in pounds of actual amitrol per acre, were 0, 1, 2, and 4. Dates of treatment and stage of vine growth at time of treatment were: May 6, white bud; May 26, few buds out ¼ inch; June 19, pink hook; July 11, late full bloom; August 6, first fruit buds forming.

The plot design was a series of five randomized block experiments with four replicates, one experiment for each treatment date. Individual plots were 10 x 10 feet in size. Data were obtained on yield, fruit size, fruit set, flower bud set and terminal growth.

## RESULTS

*General appearance of amitrol sprayed cranberry vines.*

Cranberry vines that were treated with amitrol during the active growth period, May 6, May 26, and June 19, exhibited a distinct pink color in all newly developed leaves within 7 days after treatment. The pink color was most pronounced at the leaf margins with a paler pink at the center of the leaves. In plots treated at the rate of 4 lb/A, a few leaves showed marginal browning.

The abnormal vine coloration persisted for 2 to 3 weeks and then the leaves assumed the green color normal for the time of year. The intensity of the pink color expression as well as the duration of this abnormal appearance was associated with the concentration of amitrol used; the plots receiving the highest rate showed the most severe effects. No formative effects on leaves, flowers, or fruit were observed. Applications made on July 11 and August 6 did not result in any abnormal vine color.

*Yield of berries.*

All plots were harvested "on the flood" with a conventional hand cranberry rake on September 24. Harvested berries were screened to remove extraneous trash and were weighed immediately. Plot weights, converted to barrels per acre, are presented in Table 1.

*Table 1.* Yield of cranberries following amitrol applications at five dates. (Bbl per acre).

| Date of treatment | Stage of growth at treatment | Yield cranberries, bbl/A, following treatment with amitrol, lb/A | | | | Significance |
|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 4 | |
| May 6 | White bud | 99 | 111 | 105 | 104 | N.S. |
| May 26 | Buds out ¼ in. | 82 | 85 | 83 | 75 | N.S. |
| June 19 | Pink hook | 81 | 79 | 74 | 67 | N.S. |
| July 11 | Late full bloom | 82 | 79 | 88 | 77 | N.S. |
| August 6 | First fruit buds formed | 84 | 77 | 81 | 89 | N.S. |

None of the mean differences in yield associated with the different rates of amitrol treatment approached the 5% level of significance for any of the dates of treatment. The mean yield data for the June 19 date, however, are of some interest. Production of fruit on plots treated on this date showed a fairly consistent decline as the rate of amitrol treatment increased. For the four rates 0, 1, 2, and 4 lb/A, the mean yields were 81, 79, 74 and 67 barrels per acre, respectively. Although not significant in the statistical analysis, there was an indication of some yield reduction due to treatment with amitrol at this date. The reports of Aldrich (1) and Demoranville and Cross (6) showed that yield reduction followed amitrol applications to cranberry vines at this stage of growth.

The high yield reported for all plots in the May 6 series of treatments was associated with location in the bog section. Yields in all plots in this area were consistently higher than yields achieved elsewhere in this section. No association of yield with treatment was indicated in this series of plots.

Yields of fruit in the May 26, July 11, and August 6 series of treatments were variable and could not be related to the amitrol treatments.

*Size of berries.*

A 1-quart composite sample of fruit was taken from each lot of fruit harvested. This sample was used for the determination of berry size. Size was determined by counting the number of berries required to fill a standard measuring cup. Three cup counts per plot were made to establish the size of fruit in the plots. A high cup count indicates small fruit and a low cup count indicates large fruit. The treatment means for the five dates of amitrol application are presented in Table 2.

*Table 2.* Cranberry fruit size in relation to amitrol applications at five dates (Number of berries to fill a measuring cup).

| Date of treatment | Stage of growth at treatment | Number of berries in cup, following treatment with amitrol, lb/A | | | | Significance |
|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 4 | |
| May 6 | White bud | 75 | 73 | 69 | 73 | N.S. |
| May 26 | Buds out ¼ in. | 72 | 68 | 72 | 72 | N.S. |
| June 19 | Pink hook | 73 | 74 | 78 | 74 | N.S. |
| July 11 | Late full bloom | 72 | 70 | 74 | 71 | N.S. |
| August 6 | First fruit buds formed | 71 | 72 | 70 | 71 | N.S. |

The fruit size was nearly uniform for all plots regardless of treatment. No differences associated with amitrol application were apparent in the statistical analysis. Under the conditions of this experiment it was apparent that rates of amitrol application up to 4 lb/A had no significant effect on the development of size in cranberry fruit irrespective of the date of application of the herbicide.

*Fruit set, length of upright growth, and flower bud set.*

Three samples of uprights from each plot were harvested for the determination of fruit set, length of upright growth, and flower bud set. Each sample contained all the upright growth in a randomly selected circular area of approximately 20 square inches. This sample area was chosen to provide a sample of approximately 75 uprights for measurement.

*Fruit set.* The number of flowers that were produced by all uprights and the number of berries that developed were determined for each sample. From these figures the percentage of fruit set was calculated. The data for the average fruit set per plot is presented in Table 3. The figures in parenthesis in Table 3 show the total number of flowers that were counted for the determination of each fruit set percentage.

*Table 3.* Percentage of fruit set on cranberry vines following amitrol applications at five dates.

| Date of treatment | Stage of growth at treatment | Percent of fruit set following treatment with amitrol, lb/A | | | | Significance |
|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 4 | |
| May 6 | White bud | 27(496)[a] | 28(492) | 26(564) | 22(476) | N.S. |
| May 26 | Buds out ¼ in. | 21(384) | 26(448) | 28(400) | 24(500) | N.S. |
| June 19 | Pink hook | 26(328) | 23(412) | 23(424) | 19(376) | N.S. |
| July 11 | Late full bloom | 25(476) | 29(488) | 26(516) | 26(520) | N.S. |
| August 6 | First fruit buds formed | 29(444) | 25(396) | 26(588) | 25(508) | N.S. |

[a]Figures in parenthesis show the number of flowers counted to establish each fruit set percentage.

Major differences in fruit set were not apparent from examination of the data. The most noteworthy differences were found for the series of treatments made on June 19. Treatment on this date resulted in the following fruit set percentages: untreated, 26%; 1 lb/A, 23%; 2 lb/A, 23%; and 4 lb/A, 19%. The progressive reduction in fruit set with increasing amounts of amitrol application corresponded closely to the observed differences in yield for this series of plots as shown in Table 1. The yield data were 81, 79, 74, and 67 bbls/A for the untreated, 1 lb/A, 2 lb/A, and 4 lb/A plots, respectively. Such a relationship between yield and fruit set would be expected. Data for the other dates of treatment did not show this relationship. Although the differences in fruit set were not statistically significant at the 5% level for any of the dates of treatment, the data indicated that the pink hook stage of growth was the most sensitive to amitrol effect on fruit production of the five stages of vine growth treated in this series of experiments.

*Terminal growth.* The length of seasonal terminal growth was measured for each upright in the vine samples harvested: Runners were discarded, and no attempt was made to determine the influence of amitrol on their growth.

The seasonal growth of individual uprights ranged from 10 mm to 130 mm. The average seasonal growth per upright for the various treatments is presented in Table 4. The number of uprights measured for the determination of the average growth per treatment is shown in parenthesis, adjacent to the particular mean.

*Table 4.* Average length (mm) of growth extension of cranberry uprights following amitrol treatment at five dates.

| Date of treatment | Stage of growth at treatment | Length of growth, mm, following treatment with amitrol, lb/A | | | | Significance |
|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 4 | |
| May 6 | White bud | 73(701)* | 82(719) | 76(725) | 79(732) | N.S. |
| May 26 | Buds out ¼ in. | 77(742) | 73(716) | 76(715) | 71(741) | N.S. |
| June 19 | Pink hook | 75(725) | 74(734) | 72(737) | 78(695) | N.S. |
| July 11 | Late full bloom | 75(813) | 72(754) | 72(832) | 70(780) | N.S. |
| August 6 | First fruit buds formed | 72(794) | 75(876) | 76(936) | 80(794) | N.S. |

*Figures in parenthesis show the number of uprights measured to determine the average growth.

All differences between treatment means at the several dates of application were well within the limits of experimental error. No consistent relationship between amitrol treatment and cranberry vine growth was established by the techniques used in this study. Careful observations by the author of amitrol treated plots over several years of study have never detected any reduction in upright growth from rates of application of 4 lb/A or less.

*Fruit bud set.* Each upright that was measured for seasonal growth was examined for the presence or absence of a terminal flower bud. Terminal buds that contain flower initials are larger and more plump than purely vegetative buds and may be readily distinguished from them by macroscopic examination. Any effect of treatment on flower bud formation would be reflected by a reduced flower production in the coming year.

The mean percentages of uprights examined which had terminal flower buds are shown in Table 5. Observed differences among the treatment means were well within the range of experimental error

*Table 5.* Percentage of cranberry uprights with terminal flower buds following amitrol treatment at five dates.

| Date of treatment | Stage of growth at treatment | Percent uprights with flower buds following treatment with amitrol, lb/A | | | | Significance |
|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 4 | |
| May 6 | White bud | 40 | 42 | 42 | 48 | N.S. |
| May 26 | Buds out ¼ in. | 37 | 37 | 39 | 42 | N.S. |
| June 19 | Pink hook | 44 | 42 | 40 | 42 | N.S. |
| July 11 | Late full bloom | 34 | 38 | 39 | 39 | N.S. |
| August 6 | First fruit buds formed | 42 | 43 | 42 | 45 | N.S. |

and could be attributed to random variation in the experimental material. It was interesting to note, however, that in the data for four dates, May 6, May 26, July 11 and August 6, the 4 lb/A amitrol plots had a higher bud set percentage than did the untreated controls. In the other series of plots, June 19, the average bud set for the untreated plots was 44%, which was slightly higher than the 42% for the 4 lb/A rate. These differences, though minor in total amount, lend support to the proposition that amitrol treatment does not reduce the amount of flower bud set in cranberry vines.

## DISCUSSION

Cranberry vines in the area where the experimental bog was located normally commence growth about May 1, begin to blossom approximately June 25, and the first flower buds for the succeeding year's crop are visible by August 1. The blossoming period extends over 3 or 4 weeks, the actual duration depends upon the prevailing weather conditions. Growth extension of uprights is normally completed by August 10 on vines in good production.

The treatment dates used for this experiment were selected to correspond with critical stages in the development of the cranberry vines. The May 6, May 26, and June 19 treatments were made during the period of rapid growth extension. The June 19 and July 11 treatments were made just prior to bloom and in late full bloom, respectively. The July 11 and August 6 treatments were applied as the young fruits were developing and at the critical stage for flower bud differentiation, respectively.

The amount of terminal growth, percentage of flower bud set, and size of fruit were not influenced by treatment with amitrol at the rates used. The cranberry vines had a marked tolerance of this herbicide.

The data indicated that the yield of fruit and fruit set, though not greatly reduced by any treatment at any date, were somewhat reduced by the 4 lb/A treatment made June 19. At the time this treatment was applied the first flowers were ready to open. Therefore, one could expect that the vines would be sensitive to harmful effects on fruit set at this time. Demoranville and Cross (6) also found the vines to be sensitive to amitrol effects at this season of the year. Applications of amitrol at this stage of vine development, particularly at rates of 4 lb/A or more would seem to introduce undue risk to the current fruit crop and should not be encouraged. Earlier, or later treatments were much safer from the standpoint of fruit production.

From the standpoint of weed control, no single date of application would seem to be the most important. Several weed species are sensitive to amitrol effects and each of these species undoubtedly has a period in its development when it is most sensitive to the herbicide. The problem now becomes one of finding the weakest spots in the weed developmental cycles, which do not coincide with the weakest spot in the cranberry production cycle, late June.

## SUMMARY

1. Applications of amitrol were made to a mature cranberry bog at rates of 0, 1, 2, and 4 lb/A on May 6, May 26, June 19, July 11, and August 6.
2. Each plot was harvested for total yield of fruit and sampled for fruit size, fruit set, length of growth, and flower bud set determinations.
3. Yields of fruit were not seriously reduced by any treatment, although some evidence was presented to show a slight reduction following the 4 lb/A treatment made on June 19. This treatment also was associated with a reduced fruit set.
4. Fruit size, length of upright growth, and flower bud set were not influenced by any of the treatment combinations applied.


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# Residual Herbicidal Activity of Some Chloro-Substituted Benzoic Acids in Soil[1]

W. M. PHILLIPS[2]

THE chloro-substituted benzoic acid compounds discussed here were included with a number of other chemicals tested in 1955, 1956, and 1957 as soil sterilizing herbicides at Hays, Kansas. The experiments were designed to yield information on the effectiveness of various treatments for field bindweed *(Convolvulus arvensis)* control. Results of the bindweed control studies have been briefly summarized by Phillips (9).

The residual action of soil sterilants is important in determining their over-all effectiveness and their potential hazard when used on crop land. As a part of these determinations a portion of each plot treated in 1955 and 1956 was planted to Midland grain sorghum in the spring of 1957. Sorghum emerged to a normal stand on all plots which had been previously treated with chlorinated benzoic acids. The sorghum appeared to grow normally during the early part of the season. However, shortly after heading it became evident that the crop was being adversely affected, presumably because of the toxic effects of the chemicals. Apparently normal heads were exserted from the boot of the sorghum plants but little or no grain was set in most of them. This condition was rather uniform following all rates and dates of application of the chloro-substituted benzoic acids. This study was undertaken to determine the extent of leaching and breakdown of these chemicals in the soil.

The plant hormone activity of trichlorobenzoic acid and other chloro-substituted derivatives of benzoic acid have been summarized by Zimmerman and Hitchcock (16) and Miller (7). Minarik, et al. (8) reported that the benzoic acid derivatives were more persistent in plants than was 2,4–D. Shaw and Swanson (13), Shaw (11), and Shaw, Gentner, and Jansen (12) included several chloro-substituted benzoic acids in preliminary herbicide evaluation tests. They indicated that 2,3,6–trichlorobenzoic acid (2,3,6–TBA) was more active than other derivatives of the acid. However, they also reported that when equivalent weed control was obtained, there appeared to be little or no difference in the selectivity of the various derivatives and formulations. They suggested that, due to the high initial herbicidal activity and the persistent action of these compounds, they might hold promise for pre-emergence weed control, the control of woody plants, and weed control by soil sterilization. They indicated that corn and gladioli showed excellent tolerance to pre-emergence applications of the chlorobenzoic acids, but all other crops, with the possible exception of sorghum, were susceptible.

[1]Cooperative investigations by the Crops Research Division, ARS, USDA and the Kansas Agricultural Experiment Station. Contribution No. 127, Ft. Hays Branch, Kansas Agricultural Experiment Station, Hays, Kans.

[2]Research Agronomist, Crops Research Division, Agricultural Research Service, United States Department of Agriculture.

Much of the reported weed control research with these compounds has been concerned with pre-emergence applications on crops, particularly corn (1, 5, 6, 14). Numerous tests have also been conducted to determine the effectiveness of the materials for the control of perennial weeds (2, 3, 4, 9, 15). Rates of application have varied from one to one hundred or more pounds per acre. Only a few publications have included data on the residual action of the chlorinated benzoic acid compounds. Derscheid (3) reported that TBA applied in September of 1956 caused a reduction in oat yields in 1957. Derscheid and Nash (4) applied up to 6 pounds TBA per acre on May 17, 1955. Corn planted May 26, 1955 was not seriously injured. Buchholtz (2) indicated that 2,3,6–TBA was moderately toxic to corn planted about 10 days after applications of 4 and 8 pounds per acre. He also reported that 2,3,5–TBA and 2,3,5,6–TBA gave no evidence of toxicity to corn when applied at 4 lb/A. Selleck and Alex (10) show the relative susceptibility of several weed species to 2,3,6–TBA.

## MATERIALS AND METHODS

Duplicate plots which had been treated previously with benzoic acid derivatives were sampled in January, 1958. Two chemicals were included. One was the sodium salt of a compound consisting of approximately 60% 2,3,6–trichlorobenzoic acid. Although other isomers were present in the product, it will be referred to as 2,3,6–TBA. The other chemical was an emulsifiable oil formulation of polychlorobenzoic acid (PBA), consisting primarily of several isomers of dichloro, trichloro, and tetrachlorobenzoic acids. Plots treated with 2,3,6–TBA at 15 and 30 pounds per acre on May 11, 1955, and October 18, 1955, 16 and 24 pounds on November 13, 1956, and 16 pounds on June 3, 1957, were sampled. The only available direct comparison between 2,3,6–TBA and PBA was on plots treated on November 13, 1956. Plots treated on that date with 24 pounds per acre of PBA were sampled.

The soil in the experimental area was classified as a Crete silty clay loam and had a silty clay loam topstol and a clay loam sub-soil. Samples were obtained with a power operated soil coring machine. Soil cores were removed to a depth of 6 feet. Two such cores, each approximately ¾ inch in diameter, were removed from each plot. The cores were sectioned into one-foot lengths and the corresponding foot sections of each core were pulverized and intimately mixed. After mixing, the soil was placed in cans approximately 3½ inches in diameter and 2½ inches deep. In order to prevent leaching, no holes were punched in the bottoms of the cans.

Garden beans *(Phaseolus vulgaris)* were planted as a test crop. Four bean seeds were placed on the surface of the soil in each can and covered with a uniform quantity of fine sand. The beans were planted on January 18, 1958 and began emerging on January 24. Following emergence, notes were taken at frequent intervals on visible effects of the chemicals. A numerical rating system indicated

the degree of leaf curling. A score of 100 indicated normal plants, 50-badly curled leaves, and 0-no visible plants or sprouts.

On February 13, 1958, all plants were cut at ground level, oven dried, and weighed. The dry weight of the plants was used in conjunction with notes on growth prior to harvest to formulate a growth index. Comparison of notes on average condition prior to harvest, average weight, and the calculated growth index, indicated that the three methods of presenting data were similar. Figures 1, 2, and 3 give results in terms of average weight per plant of the bean plants harvested. Pictures shown in Figures 4, 5, and 6 illustrate the results more graphically than the numerical data.

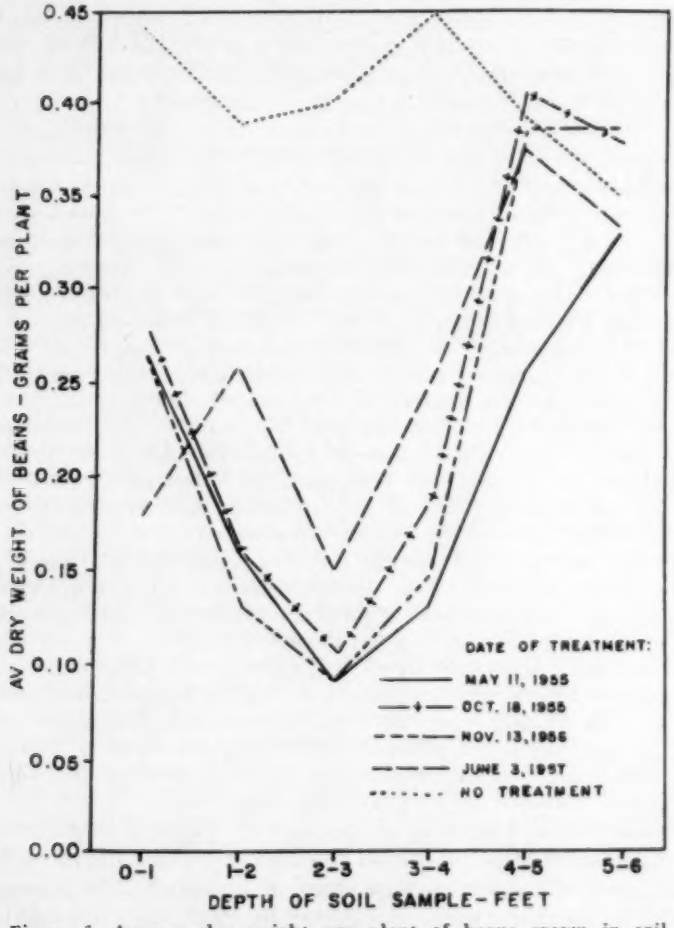


*Figure 1.* Average dry weight per plant of beans grown in soil previously treated with 15 or 16 lb/A 2,3,6-TBA, sampled January, 1958.

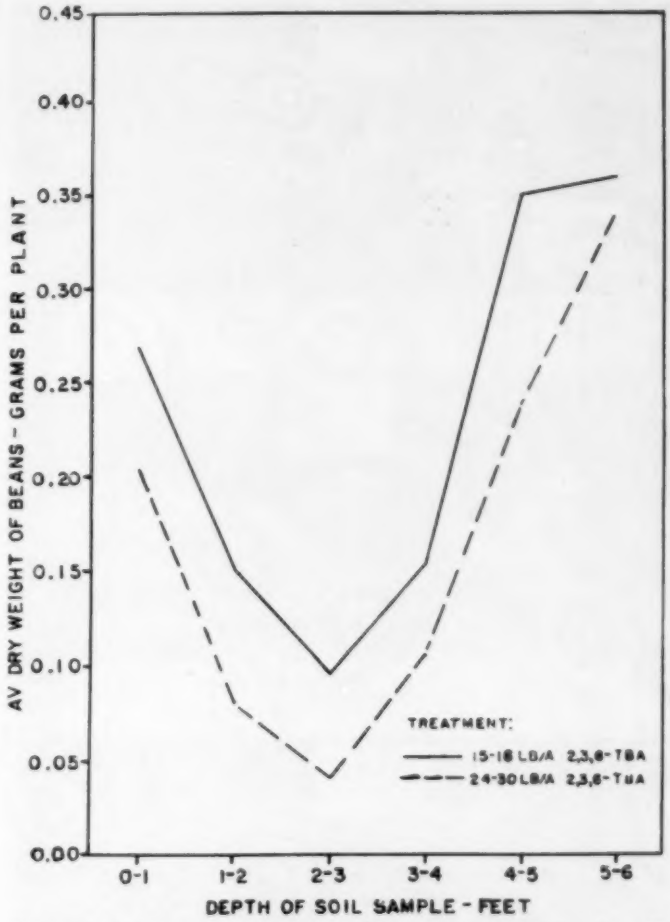


*Figure 2.* Average dry weight per plant of beans grown in soil previously treated with 2,3,6–TBA. Data are averages of three treatment dates, May 11, 1955, October 18, 1955 and November 13, 1956.

## RESULTS

Factors on which data are available include: (1) the movement and persistence of the residual activity of these benzoic acids in a Crete soil, (2) the effect of rate of application on their residual activity and (3) a comparison of the initial and residual activity of 2,3,6–TBA and PBA.

Figure 1 shows the average dry weight of bean plants harvested from the cans containing soil from plots treated with 15–16 lb/A 2,3,6–TBA. Also shown are the average weights of plants grown on untreated soil taken from the indicated depths. There was no appar-

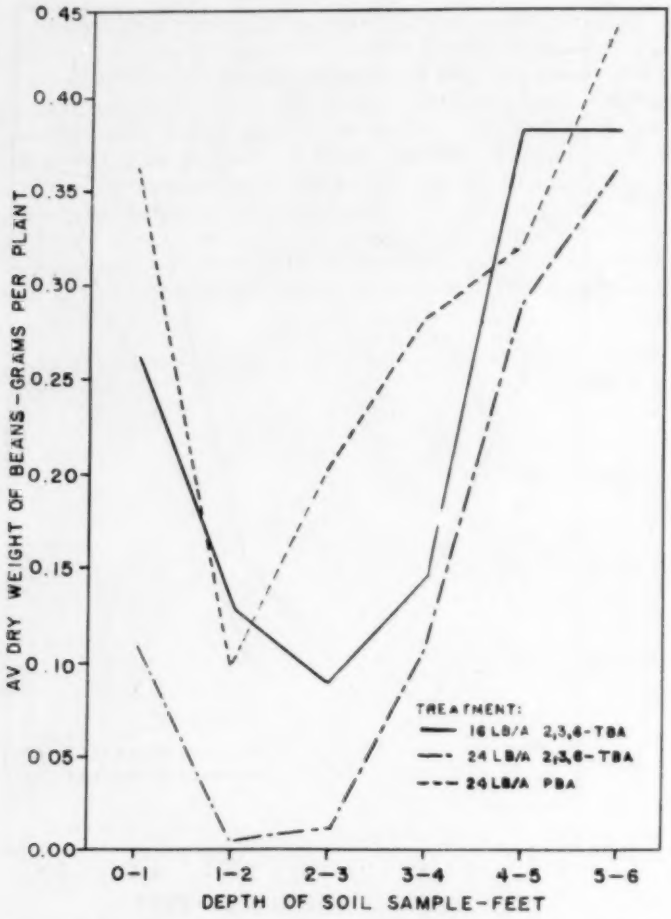


*Figure 3.* Average dry weight per plant of beans grown in soil treated November 13, 1956 with 2,3,6–TBA or PBA.

ent difference in the bean plants growing on untreated soil, regardless of the depth from which it was obtained. Soil from plots treated May 11, 1955, October 18, 1955, and November 13, 1956, produced bean plants of similar size. This was particularly true in the upper four feet of soil. It appears that the herbicide applied in May, 1955, had leached to a slightly lower depth than on other dates. In no case was there indication of large amounts of the chemical in the sixth foot of soil. Although application of 2,3,6–TBA made June 3, 1957, caused a similar growth pattern, the overall toxicity of this treatment did not appear to be as serious as that caused by the earlier treatments. Figures 4 and 5 show bean plants growing in soil taken from field plots treated on the four indicated dates.

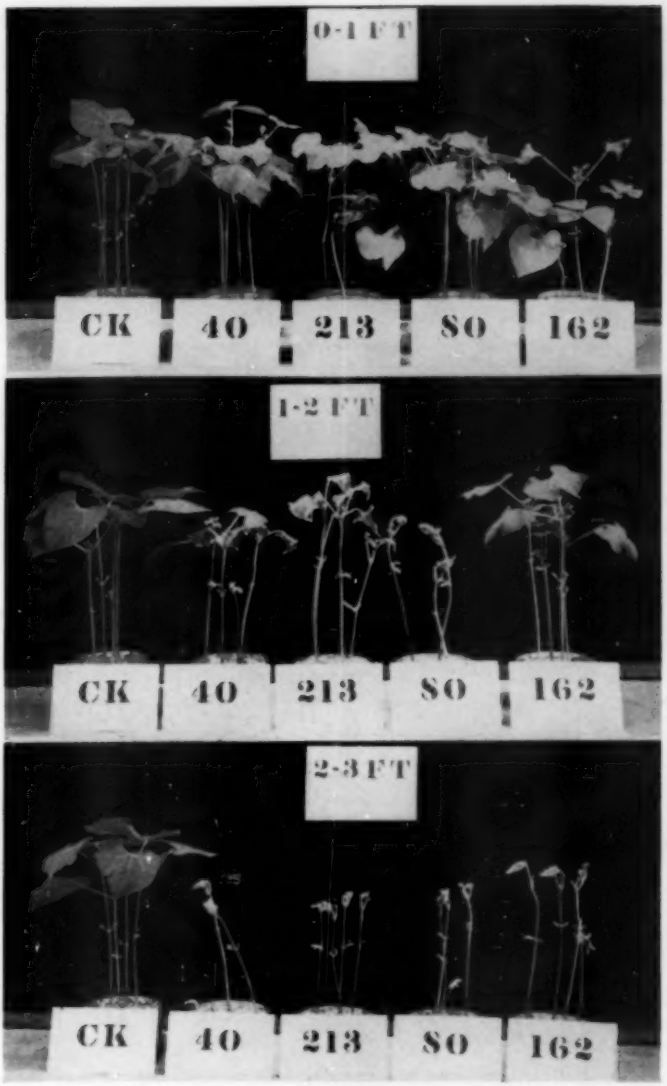


*Figure 1.* Beans growing in successive feet, as indicated, of soil from plots treated with 15–16 lb/A 2,3,6–TBA. Dates of treatment were: 40–May 11, 1955, 213–October 18, 1955, 80–November 13, 1956 and 162–June 3, 1957. Sampled January, 1958.

Figure 2 shows the combined average weight of bean plants harvested from soil treated with two rates of 2,3,6–TBA May 11, 1955, October 18, 1955, and November 13, 1956. The higher rate resulted in an increase in the herbicidal activity remaining in the

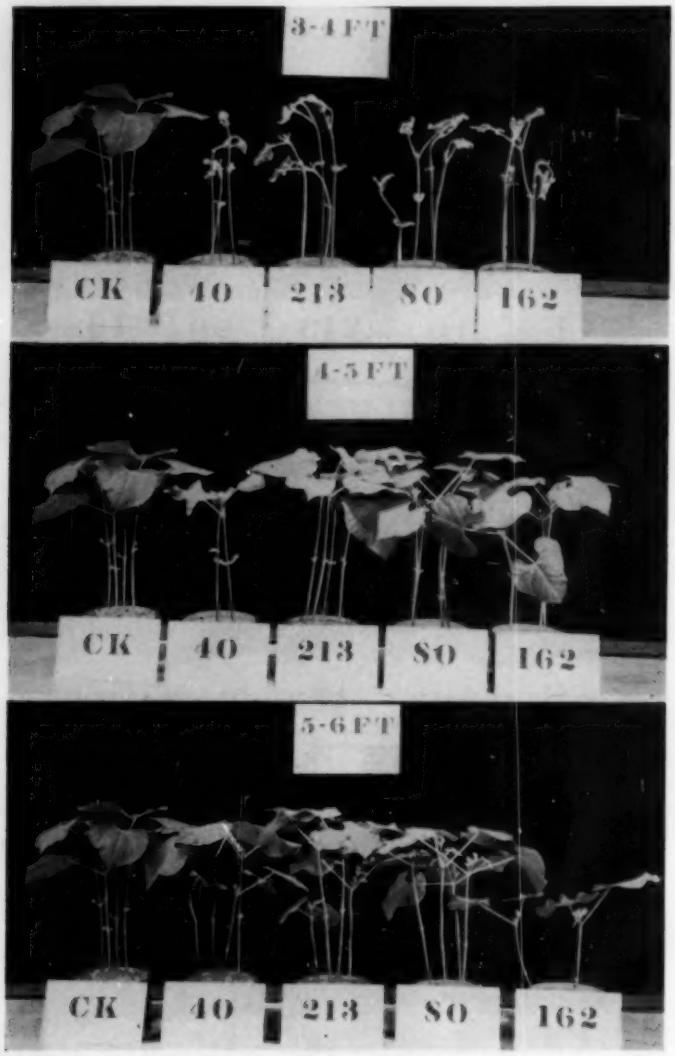


*Figure 5.* Beans growing in successive feet, as indicated, of soil from plots treated with 15–16 lb/A 2,3,6–TBA. Dates of treatment were: 40–May 11, 1955, 213–October 18, 1955, 80–November 13, 1956 and 162–June 3, 1957. Sampled January, 1958.

soil, but otherwise the two rates caused similar reactions. Figure 6 middle shows bean growth in soil treated with 24 lb/A 2,3,6–TBA. Not all plots exhibited such severe symptoms but the figure illustrates the general pattern of chemical effect. Of the plots sampled, only those treated with 24 or 30 lb/A 2,3,6–TBA retained sufficient

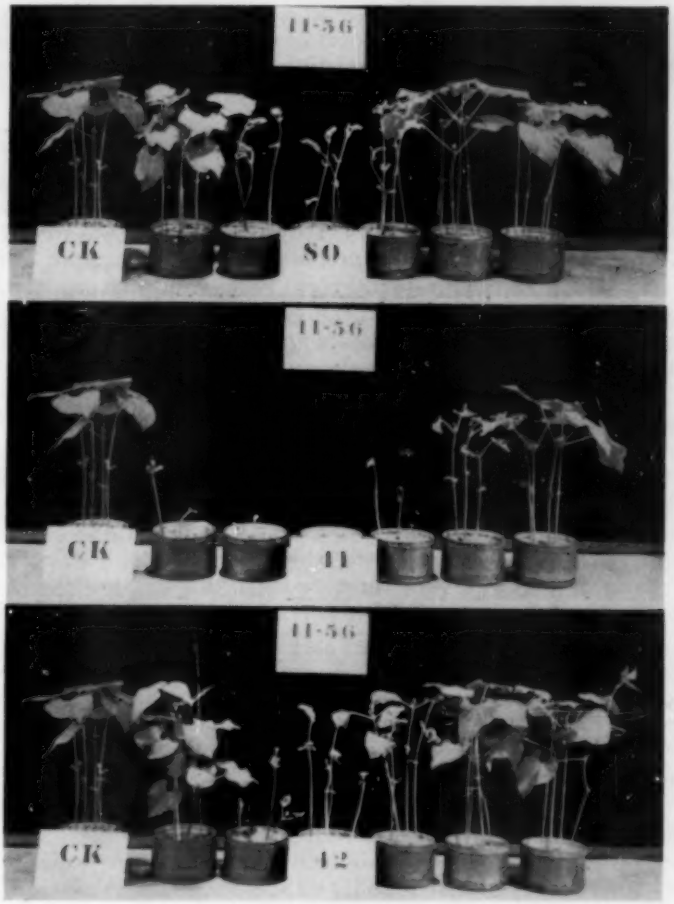


*Figure 6.* Bean plants growing in one foot increments of soil (left to right: no treatment, 1st, 2nd, 3rd, 4th, 5th, and 6th foot) from plots treated November 13, 1956 and sampled January, 1958. Top, (80), treated with 16 lb/A 2,3,6–TBA; middle, (41), 24 lb/A 2,3,6–TBA; bottom, (42), 24 lb/A PBA.

residual toxicity to interfere with germination and emergence of the beans.

Figure 3 shows the results obtained when beans were grown in soil which came from plots treated in November, 1956. It is readily noted that 24 lb/A 2,3,6–TBA caused virtually complete failure of beans planted in the second and third feet of soil. Only limited bean growth occurred in the first and fourth feet. Nearly normal growth was produced in the fifth and sixth feet of soil. The 16 lb/A rate of 2,3,6–TBA caused a similar growth pattern, but the injury was not so severe as with the higher rate. Figures 3 and 6 indicate that, at

most depths, 16 lb/A 2,3,6–TBA had a greater degree of herbicidal activity than 24 lb. PBA. This level of activity substantiates earlier observations by Phillips (9) concerning the relative degree of bindweed control by the two materials.

## DISCUSSION AND CONCLUSIONS

Table 1 gives the rainfall data for Hays, Kansas, for the years 1955, 1956, and 1957. It may be noted that, except for September, 1955, the period from January, 1955, to March, 1957, was dry. Rains received in September, 1955, caused moisture to penetrate the dry soil to a depth of about three feet. Following that time severe drought conditions existed until the spring of 1957; thus, it appears doubtful that any of the chemicals applied after September, 1955, could have been leached below the surface 1 or 2 feet prior to the 1957 growing season. Beginning in March, 1957, adequate precipitation was received for a period of several months. During 1957, some moisture penetrated to comparatively deep levels in the soil. At the time of sampling for this experiment, the soil contained some moisture throughout the entire six feet.

*Table 1.* Precipitation by months at Hays, Kansas during 1955, 1956, and 1957.

| Year | Month | | | | | | | | | | | | Total[a] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan. | Feb. | Mar | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | |
| | Inches of precipitation | | | | | | | | | | | | |
| 1955 | 0.45 | 0.64 | 0.15 | 3.01 | 2.48 | 3.70 | 2.09 | 0.51 | 7.63 | 0.16 | 0.09 | 0.25 | 21.16 |
| 1956 | 0.63 | 0.60 | 0.17 | 1.28 | 1.42 | 0.38 | 2.79 | 1.07 | 0.06 | 0.74 | 0.05 | 0.02 | 9.21 |
| 1957 | 0.19 | 0.11 | 2.44 | 2.14 | 4.08 | 6.74 | 3.11 | 3.92 | 3.49 | 1.22 | 0.80 | 0.09 | 28.33 |

[a]90-year average is 22.84 inches.

The striking similarity of the curves in Figure 1 indicate that the length of time 2,3,6–TBA had been applied to the soil did not greatly affect the residual toxicity of the chemical. Although little specific information is available concerning the breakdown of the chloro-substituted derivatives of benzoic acid in the soil, the data presented show that much of the remaining toxicant had been distributed through a depth of about 4 feet of soil.

The curves shown in Figures 1 and 2 suggest a logical explanation for the condition of the sorghum which grew on the plot area. Reports from Shaw et al. (12) and observations made in the greenhouse in connection with this study indicate that sorghum has some tolerance to the benzoic acid herbicides. It is concluded that, although beans were affected in the greenhouse, the herbicide was not present in the upper 2 feet of soil in sufficient quantities to greatly affect the sorghum in the field. The crop was planted on June 6 and sufficient rainfall was received during June and July to provide adequate moisture for crop growth. During the latter part of July and early August, the crop exhibited some drought stress. It is presumed that during this period of stress, the sorghum roots

penetrated more deeply and reached the zone of greater chemical concentration.

It may be concluded that, under conditions of the field and greenhouse experiments described, chloro-substituted derivatives of benzoic acid, or phytotoxic products of their breakdown, are quite persistent in the soil. It appears that it would be impossible to grow sensitive crops for a considerable period following application of these chemicals at rates necessary for soil sterilization.

## SUMMARY

Soil samples were taken in January, 1958, from plots treated with 15 to 30 lb/A 2,3,6–trichlorobenzoic acid (2,3,6–TBA) on May 11, 1955, October 18, 1955, November 13, 1956, and June 3, 1957, and from plots treated with 24 lb/A of a polychlorobenzoic acid (PBA) on November 13, 1956. Samples were taken to a depth of 6 feet and beans were planted in each one foot increment of soil. Emergence, growth abnormalities, and size of bean plants were noted as measures of the residual herbicidal activity of these materials.

The length of time between application of 15–16 lb/A 2,3,6–TBA and soil sampling did not greatly affect the disappearance or distribution of the herbicide. Most of the residual activity was concentrated in the second, third, and fourth feet. Higher rates of 2,3,6–TBA, 24 or 30 lb/A, were carried to the same depths, but the effects on the beans were more severe.

Soil from all depths sampled on plots treated in November, 1956, with 24 lb/A PBA was less toxic to beans than soil from plots treated with 24 lb/A 2,3,6–TBA. At most depths, 16 lb/A 2,3,6–TBA caused as much or more damage to beans than did 24 lb/A PBA. None of the treatments appreciably affected beans grown in the sixth foot of soil.

Precipitation during much of 1955 and 1956 was not sufficient to wet the soil more than 2 to 3 feet below the surface. The toxicant in the treated plots could not have been leached deeply into the soil until the high rainfall during 1957.

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# The Translocation of 2,4–D–1–$C^{14}$ in *Potamogeton pectinatus*, a Submersed Aquatic Plant[1]

F. D. Aldrich[2] and N. E. Otto[3]

## Introduction

The question of direction and rate of movement of herbicidal chemicals in aquatic plants often arises in considering effective methods of chemical control for plants of this type. Results obtained from studies of solute movement within terrestrial plants are not directly applicable to totally submersed aquatic species for two reasons: a) A liquid medium, in which dissolved substances may be distributed uniformly, surrounds all parts of the aquatic plant, and b) Vascularization is minimal in leaf and stem tissues of submersed aquatics. Reports of experiments yielding quantitative data on translocation patterns in submersed aquatic plants are rare or nonexistent. It is probable that mechanical difficulties encountered in separating root systems from leaf or stem tissues of submersed plants have been of greater hindrance to translocation experiments with aquatic species than any other factors.

The early work of Pond (4) suggested that roots of *Anacharis (Elodea)* serve for absorption of nutrients as well as for anchorage in substratum, as evidenced by retarded mineral uptake in non-rooted plants. Oborn et al. (3) reported that radioactive 2,4–D moved from the point of application to rhizomes of *Potamogeton nodosus* and *Typha latifolia*. These plants, while considered as typical of submersed and emergent aquatics, respectively, have floating or aerial leaves which serve as convenient loci of treatment in experimental work. Recent compilations (2) indicate that the root systems of submersed aquatics may serve primarily as anchoring devices or perennating organs.

Prerequisite to any successful experiment intended to measure the uptake and translocation of solutes by submersed aquatic plants is a means of isolating the root system from stem and leaf tissues while maintaining optimum fluid environments for each phase. Various materials and techniques were explored in an attempt to accomplish this. One satisfactory method is described here, together with some experimental results obtained from measurements of translocation of carboxyl-labeled 2–4–dichlorophenoxyacetic acid (2,4–D–1–$C^{14}$) in *Potamogeton pectinatus* (Sago pondweed).

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## METHODS

The extreme elastic properties of thin latex membranes were found to be adaptable for sealing root systems from upper stem and leaves of *P. pectinatus* plants (Figure 1).

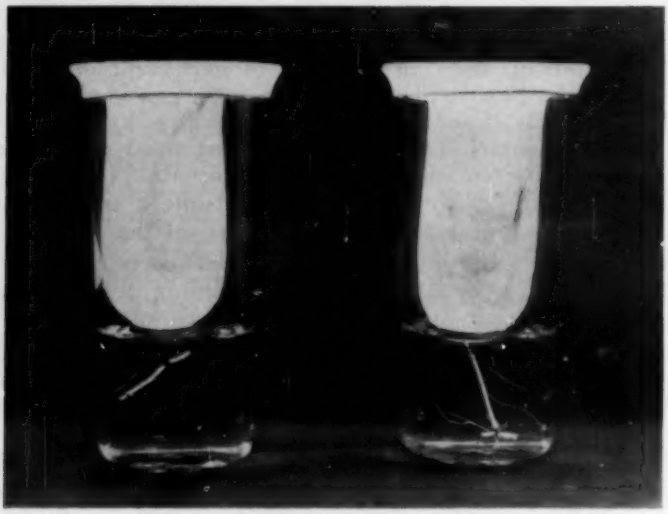

*Figure 1.* Latex membrane assemblies with plants and buffer solutions in place.

The membranes were first stretched tightly over the mouth of a 180-ml Berzelius (tall pattern) beaker. The exact center of the stretched membrane was lightly perforated with the point of a red-hot, sharpened needle, making a hole approximately one millimeter in diameter. A ring of silicone grease was applied to the edge of the hole by gently twirling a greased cotton swab over the orifice. The membrane was then removed from the beaker, whereupon the hole either closed completely or presented only a pinpoint-sized opening.

Plants averaging 8 inches in length and devoid of tubers were selected from regrowth arising from a mature parent clone. To assemble a plant to a membrane, the latter was stretched carefully between the hands to enlarge the perforation to approximately 3 mm. diameter. The single plant, leaves first, was threaded through the opening. When the junction between green stem tissue and chlorotic root was located at the orifice, the membrane was released. The hole contracted to surround the stem, forming a seal lubricated by the thin ring of silicone grease. The inner part of the membrane, containing leaves, was filled with water and the sealing edge of the hole examined for leakage. No seepage was apparent if the plant stem was uniformly round and smooth, and if the hole in the membrane had not been torn or otherwise damaged during insertion of the plant. This assembly required two operators.

Fifty ml of pH 7.4, 0.025 M phosphate buffer were introduced into a 180-ml tall beaker. The root system external to the membrane was lowered into this solution. The upper part of the membrane was rolled back over the lip of the beaker to fasten it in place. Another 50 ml of buffer solution were placed in the inner part of the membrane to surround the leaves.

Two checks were made on the efficiency of the sealing membrane. First, methylene blue dye was placed in the inner phase of the assembly to test the durability of the seal between stem and membrane. Observations for five days revealed no visible leakage of color past the stem into the lower solution. A second check was designed to measure the migration of radioactive 2,4–D across an intact membrane. Ten microcuries of 2,4–D–1–$C^{14}$ were placed in the outer phase of one assembly and a similar quantity in the inner phase of another one. One-ml aliquots of solution from the inner and outer phases of each assembly were removed at intervals of 8 and 72 hours, transferred to stainless steel cup planchets, dried, and assayed for total radioactivity (Table 1). It is apparent that a small amount of migration did occur across the latex membranes, but was of slight significance in eight hours. At 72 hours, the non-treated phases showed activities which were deemed to be excessive for reliable results with plant material. Consequently, the exposure periods were limited to a maximum of 24 hours.

*Table 1.* Loss of 2,4–D–1–$C^{14}$ across latex membranes.

| Path of flow | Counts per minute in 1 ml.[a] | | | |
|---|---|---|---|---|
| | 8 hours | | 72 hours | |
| | Inner | Outer | Inner | Outer |
| Outward | 150,300 | 46 | 160,000 | 720 |
| Inward | 43 | 171,600 | 594 | 172,000 |

[a]Radioactivity (c.p.m.) in 1.0-ml. aliquots of buffer solution (pH 7.4, 0.025 M) withdrawn from treated and untreated phases of latex membrane assemblies. Membranes were intact.

After the plant-and-membrane assemblies were completed, three sets of plants were treated in duplicate, two each in the inner phase (leaves) and two each in the outer (root) phase. A total of 12 treatments were made, comprised of six sets of duplicate treatments. One ml of solution containing 3.5 microcuries of 2,4–D–1–$C^{14}$ was introduced into each assembly with a hypodermic syringe and 22-gauge needle. At intervals of 6, 12 and 24 hours, two each of the leaf-fed and root-fed plants were harvested. The plants were rinsed thoroughly in running water, blotted to surface-dryness between several layers of filter paper, and cut at the point on the stem surrounded by the membrane seal. Root and stem (leaf) tissues were weighed separately, placed between blotters, and air-dried.

A Pregl ignition method was used to burn each dry root and leaf sample in a stream of oxygen at 1000°F. Evolved $CO_2$—$C^{14}O_2$ was trapped in 0.2 N NaOH and precipitated with 0.5 N $BaCl_2$ in 0.4 N

$NH_4Cl$. This procedure yielded carbonate samples representing total radioactivity present in each tissue sample.

Carbonate discs were prepared by filtration on filter paper circles mounted on a sintered-glass filter.

The discs, after drying and heat treatment, were assayed in an alpha-beta-gamma proportional counter employing a still gas atmosphere of 10% methane and 90% argon, at a chamber potential of 1800 volts.

## RESULTS

Figure 2 illustrates the specific activity (c.p.m./mg. fresh wt.) obtained from pairs of root and leaf samples at 6, 12, and 24 hours. This method of presenting results places each sample on an identical basis, even though sample weights may vary within wide limits. No

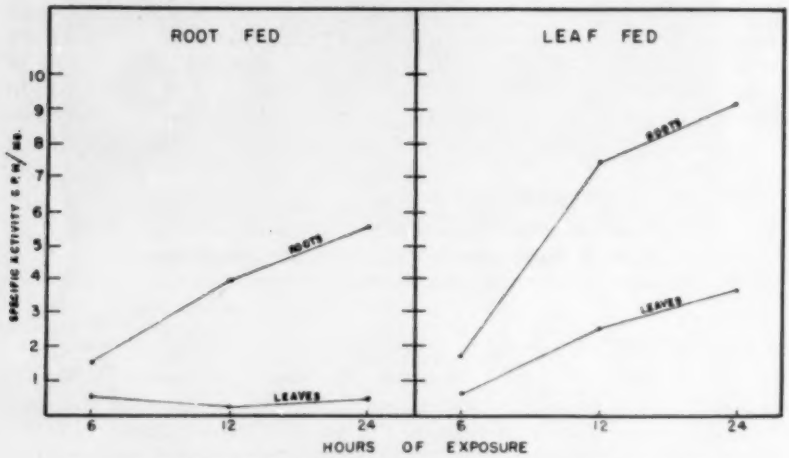


*Figure 2.* Specific activity of root and leaf samples of *P. pectinatus* at increasing intervals of exposure to carboxyl-labeled 2,4–dichlorophenoxyacetic acid.

attempt was made to determine and plot the percentages of radioactive material taken up or translocated. In previous work with terrestrial plants and with emergent aquatics (1,3) applications were made in a single spot with measured quantities of material, permitting ready calculation of uptake and distribution of radioactivity throughout various plant organs.

From the data obtained, it is quite clear that basipetal movement of radioactivity was much more rapid than that in an upward direction. This is shown in Figure 2 as a nearly horizontal plot of specific activity in leaf tissue from root-fed plants, and as a steeply-rising value for roots from leaf-fed plants.

Accumulation of radioactivity in roots was marked in plants receiving 2,4–D–1–$C^{14}$ from either route. These observations concur with those made on many types of terrestrial plants and on *Typha*

and *P. nodosus*. In view of the small amount of vascular tissue present in most submersed aquatic plants, it is interesting that downward movement of materials is as extensive as the present data indicate.

## SUMMARY

Thin latex membranes were used to isolate roots from upper stem and leaf tissue of *Potamogeton pectinatus* in order to permit application of carboxyl-labeled 2,4–D to each system separately. Individual plants were fed with this compound for intervals of 6, 12 and 24 hours, harvested and assayed for specific activity in root and leaf tissues.

Data indicate that movement of radioactivity was primarily in a downward direction in plants receiving 2,4–D–1–$C^{14}$ in leaves. In both root-fed and leaf-fed plants, accumulation of radioactivity was more extensive in roots than in leaves.

## ACKNOWLEDGMENTS

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# The Absorption and Translocation of $C^{14}$-Labeled Simazin by Corn, Cotton, and Cucumber

D. E. Davis, H. H. Funderburk, Jr., and N. G. Sansing[1]

Simazin, 2–chloro–4,6–bis(ethylamino)–*s*–triazine, is a relatively new herbicide that has shown much promise for pre-emergence weed control in corn (3,4,7). It is a white crystalline compound with a solubility of 5 ppm in water and 900 ppm in chloroform. This compound is non-flammable, non-corrosive, and has an acute oral toxicity greater than 5 g/kg for mice. Simazin is said to be highly toxic to cucumber, of intermediate toxicity to cotton, and non-toxic to corn.[2] Schneider (6) reported it to be effective only when absorbed through the root system. This study was begun to determine whether the differences in susceptibility of these plants and the limitation of effectiveness of simazin to the root system could be correlated with its absorption and translocation.

## Materials and Methods

The absorption and translocation of radioactive simazin[3] was studied in corn, cotton, and cucumber. The simazin was tagged with $C^{14}$ at the 2, 4, and 6 positions in the triazine ring and had a specific activity of 0.83 mc per mM. A 100 ppm simazin suspension was prepared by mixing 0.1 mc (24.2 mg) of the labeled material with 242 ml of water. Water-culture nutrient solutions were treated with 20 ml of this suspension for each 500 ml bottle, giving cultures with 4 ppm simazin. Radioassay of the cultures established that the activity was comparable in each bottle and evenly distributed throughout the bottles.

Two radioassay procedures were used in each experiment in this study. The first was counting in a gas-flow Geiger counting assembly and the second was autoradiography. In the usual method of autoradiography, the roots were separated from the shoot and processed separately. The roots were rinsed, blotted with paper toweling, and dried and pressed in a conventional plant press. The stem and leaves were also pressed and dried in a like manner. A freeze-dry technique, such as described by Crafts (1), was used in two experiments dealing with the effect of time on the absorption and translocation of simazin. The plants, whether dried while frozen or in the conventional manner, were then mounted on heavy paper, covered with Saran Wrap, and placed in contact with no-screen X-ray film for the 2½-week exposure period. There were check plants for each treatment in each experiment.

The plants for these studies were grown either in nutrient culture or in soil in 4-in pots. All experiments conducted in nutrient culture,

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[2]Personal communication from C. C. Alexander of Geigy Agricultural Chemicals.

[3]Supplied by the Geigy Chemical Company.

with the exception of those dealing with time, were run in duplicate, whereas the experiments conducted in soil were replicated three times. The nutrient culture was continuously aerated and was Solution 2 described by Hoagland and Arnon (2). The plants were germinated in moist sand, and transferred to nutrient culture about 1 week after planting. After the plants were growing well, they were transferred to similar nutrient solutions containing radioactive simazin. Daily additions of deionized water maintained the nutrient culture level. At the end of each experiment, all simazin-containing solutions were mixed together and refrigerated until used again for the next experiment. New radioassays were made each time to ensure adequate levels of activity and uniform simazin distribution among the bottles.

The first three experiments were conducted to establish the relative tolerances of the test plants and the nature of absorption and translocation of simazin by the three different species. In Experiment 1 the plants were kept in nutrient culture for 2 days and in the simazin solution until injury symptoms appeared. This was 4 days for cucumber, 6 days for cotton, and 15 days for corn, although no injury except stunting occurred to the latter species. In Experiment 2 the plants were kept in the nutrient solution for 9 days, and the period in simazin solution was 4 days for cucumber and 5 days for cotton and corn. In Experiment 3 the plants were kept in nutrient solution for 5 days and all 3 species in simazin solution for 4 days. In all three experiments the plants were harvested and dried in a plant press as described previously. A 1 x 3 cm sample was cut from the dried roots and leaves for counting prior to autoradiography.

The next three experiments dealt with the effect of the length of time in simazin solution on its absorption and translocation. Experiment 4 used corn only and the time intervals were 2, 4, and 6 days. Experiment 5 was a continuation of 4, the time intervals being 1, 2, 4, 8, 10, and 24 hours. In Experiment 6 cucumber was used instead of corn with time intervals of 0.5, 1, 2, 4, and 18 hours. The freeze-dry procedure was used in all three of these experiments.

The two following experiments involved absorption and translocation of simazin from a Norfolk sandy loam soil. In Experiment 7, simazin at 3 lb/A was applied to the soil surface after the three different crops were planted. The pots then were subdivided into two groups, half being watered from above by a 1 in simulated rain and the balance subirrigated. All plants were harvested 17 days after planting. At the completion of the experiment, all soil was composited and the simazin thoroughly mixed through the soil for use in Experiment 8. This experiment was the same as 7, except that all pots were watered from below and only cotton and corn were used.

Three additional experiments dealt with foliar absorption and translocation of simazin. Experiment 9 compared absorption by leaves of corn plants whose roots were in nutrient culture with the foliar absorption of plants whose roots were in 5 per cent NaCl

solution. The tip 3 inches of the third leaf were placed in 4 ppm simazin solution containing a 1 per cent surfactant, Trend. This leaf and root treatment was maintained for 30 minutes. The leaves were then rinsed and all roots placed in normal nutrient solution for another 20 hours before harvesting. Experiment 10 used the same procedures, except that the corn leaves were held in radioactive simazin solution for 24 hours prior to being exposed to the two root treatments for an additional hour and 20 minutes. Experiment 11 used all three plant species and compared absorption and translocation through intact leaves with that through leaves whose upper surfaces were lightly scratched with fine sandpaper. The leaves were submerged in simazin solution for 48 hours.

Experiment 12 was concerned with chloroform extraction of $C^{14}$-tagged simazin and/or other tagged soluble compounds from the dried corn, cotton, and cucumber plants grown in Experiment 2. The activity of a leaf from each species was measured and the leaves were then ground individually using a mortar and pestle with acid-washed sand and chloroform. The ground material was placed in a Seitz filter and washed several times with chloroform. Forty ml of chloroform were used for the grinding and washing procedure. The filtrate was evaporated so that only 2 to 5 ml remained and the activity was determined for a 1 ml aliquot.

## Results and Discussion

The radioactivity present in random leaf samples from Experiments 1, 2, and 3 is given in Table 1. If the activity recorded in the leaves is proportional to the amount of simazin absorbed by the plant, then the following inferences can be made. First, there is no obvious correlation between susceptibility and the amount of simazin absorbed by the plant. Second, the concentration of simazin apparently continues to rise in the plant for a considerable period of time. Since the radioactivity present in the leaves may be simazin or $C^{14}$-labeled degradation products and since the activity translocated to the leaves may not be proportional to that absorbed, the above conclusions are subject to possible modifications.

*Table 1.* The effect of time in radioactive simazin solution and species of plant on the radioactivity of leaf samples.

| Experiment number | Days in simazin solution | Plant | Counts per minute |
|---|---|---|---|
| Exp. 1 | 15 | Corn | 7,720 |
| | 6 | Cotton | 6,930 |
| | 4 | Cucumber | 2,970 |
| Exp. 2 | 5 | Corn | 2,720 |
| | 5 | Cotton | 3,720 |
| | 4 | Cucumber | 5,480 |
| Exp. 3 | 4 | Corn | 630 |
| | 4 | Cotton | 270 |
| | 4 | Cucumber | 680 |

The distribution of simazin or its $C^{14}$-labeled degradation products in the leaves of the test plants is shown in Figure 1. These autoradiograms are from plants in the third experiment, but are similar to those from Experiments 1 and 2. There is a marked tendency toward marginal accumulation in the susceptible cucumber as opposed to the general distribution in the non-susceptible corn. Cotton is intermediate both in degree of susceptibility and in tendency toward localized distribution of the chemical. The heavy accumulation of radioactive material in the leaf margins of cucumber is closely correlated with the development of necrosis in this area, and would seem to indicate that the radioactive material is simazin or a biologically active degradation product. Conversely the activity in corn would be presumed not to be simazin since it is

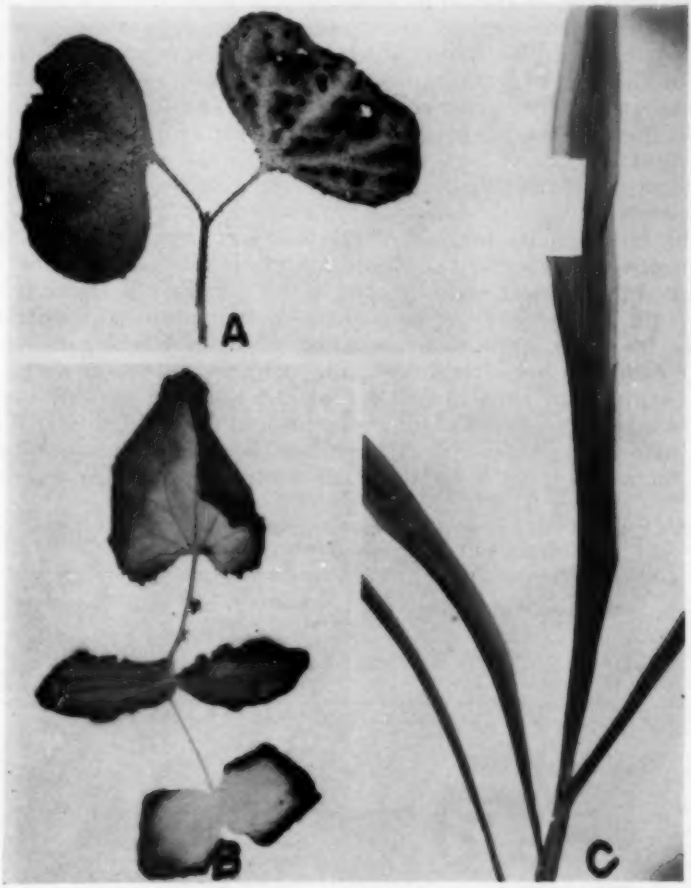


*Figure 1.* The distribution pattern of simazin or $C^{14}$-labeled degradation products in (A) cotton, (B) cucumber, and (C) corn, after 4 days in tagged simazin solution.

not biologically active and since its distribution pattern is different from that in cucumber. The work of Roth (5) on the degradation of simazin by expressed corn sap substantiates this supposition. The spotty distribution of activity in cotton is apparently caused by an accumulation of radioactive material in the lysigenous glands present in the stem and leaves of this plant. The marginal accumulation in cucumber and in the glands of cotton may indicate that simazin is largely a xylem mobile compound. If the glands are sites of high transpiration and if simazin does not move readily from the xylem into the interveinal areas, then it would be swept along in the transpiration stream and accumulate at the edges, glands, and other sites of high transpiration. This would explain the burning of leaf edges characteristic of simazin injury.

The response of the crops to simazin in Experiment 1 confirmed the previously reported relative susceptibilities. There was, however, stunting of corn by simazin, which has not been reported. Corn that had been in the simazin solution for 17 days averaged 18 inches tall as compared with 29 inches for the check. The stunting effect was less in the other two experiments where the time in simazin solution was shorter. These values were 20 inches for the check versus 18 for the simazin solution in Experiment 2 and 22 inches versus 16 for Experiment 3.

The radioactivity present in random leaf samples from Experiments 4, 5, and 6 is given in Table 2. Simazin is apparently absorbed readily by the roots of both corn and cucumber. Radioactivity is observable in the leaves of corn after 8 hours and in cucumber after 0.5 hour. There appears to be some tendency for the absorption curve to flatten out after 4 days. This may merely reflect decreasing concentration of simazin in the nutrient solution or may involve loss of activity from the plant in the form of $C^{14}$-labeled $CO_2$. There was little or no increase in activity when the time in simazin solution was increased from 8 to 18 or 24 hours. The longer exposures

*Table 2.* The effect of time on the uptake of simazin by corn and cucumber as measured by the radioactivity of leaf samples.

| Experiment number | Time in simazin solution | Plant | Counts per minute[a] |
|---|---|---|---|
| Exp. 4 | 2 days | Corn | 900 |
| | 4 days | Corn | 2,200 |
| | 6 days | Corn | 2,600 |
| Exp. 5 | 1 hour | Corn | 0 |
| | 2 hours | Corn | 0 |
| | 4 hours | Corn | 0 |
| | 8 hours | Corn | 220 |
| | 10 hours | Corn | 265 |
| | 24 hours | Corn | 166 |
| Exp. 6 | 0.5 hour | Cucumber | 35 |
| | 1 hour | Cucumber | 180 |
| | 2 hours | Cucumber | 189 |
| | 4 hours | Cucumber | 1,100 |
| | 8 hours | Cucumber | 1,940 |
| | 18 hours | Cucumber | 1,140 |

[a]The counts are averages from two samples in Experiments 4 and 6 and from a single replication in Experiment 5.

involved a night period, one of low transpiration, whereas all shorter periods were in full daylight. This suggests again that simazin probably moves through the xylem with the transpiration stream.

The effect of time on distribution and concentration of simazin, or a biologically active degradation product, in the leaves of cucumber is shown in the autoradiograms in Figure 2. These autoradiograms were made from plants subjected to the freeze-dry technique. The corn plants in Experiment 4 were dried in the conventional manner and the autoradiograms were similar to that of corn in Figure 1. The corn plants in Experiment 5 were subjected to the freeze-dry technique, but shattered so badly that no autoradiograms were made. A study of figure 2 shows that the radioactive material reached the leaf within 30 minutes and that the characteristic

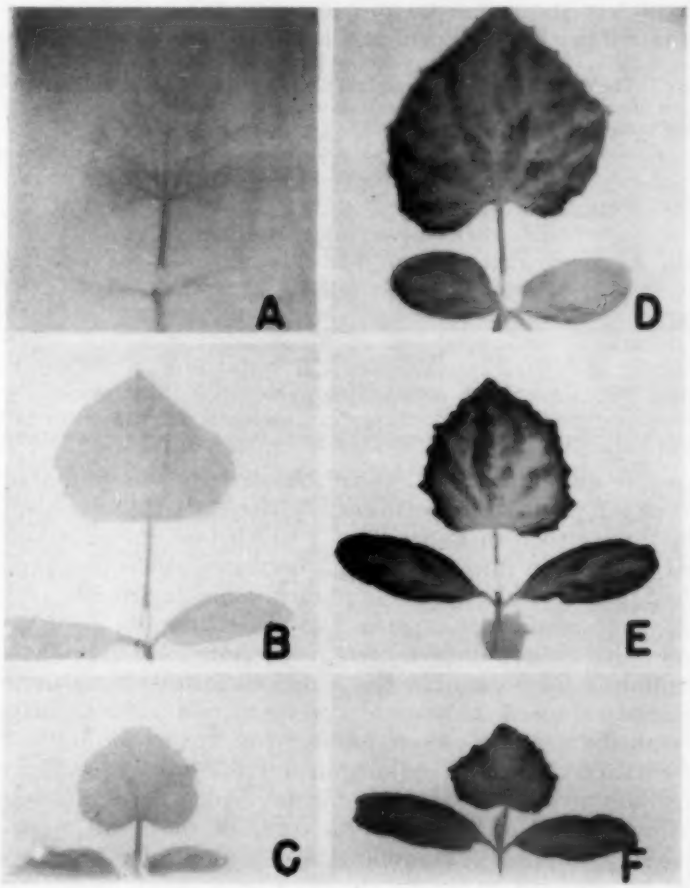


*Figure 2.* The distribution pattern of simazin or $C^{14}$-labeled degradation products in cucumber after: (A) 0.5 hr., (B) 1 hr., (C) 2 hr., (D) 4 hr., (E) 8 hr., (F) 18 hr. in tagged simazin solution.

marginal accumulation had commenced within 8 hours. Since these had been subjected to the freeze-dry technique, this was not an artifact induced by movement during drying. The activity was first limited to the veins but later became primarily interveinal. The simazin apparently moved up through the xylem and out into the interveinal area where it accumulated.

The effect of the simulated rainfall, plant species, and method of application of radioactive simazin to the soil on the radioactivity in plant leaves is shown in Table 3. When radioactive simazin was applied to the soil surface, simulated rainfall increased the radioactivity in the leaves as compared with that in subirrigated plants. Apparently surface watering increased the simazin in the root zone and hence its absorption. Cotton leaves have significantly more activity than corn leaves growing in the same pot. This could be a result of less absorption by the corn plant, less mobility of the degradation products in corn, or a loss of activity from the plant as

*Table 3.* The effect of simulated rainfall, plant species, and method of application of simazin on its absorption from soil as measured by radioactivity in leaf samples.

| Experiment number | Treatment | | Plant | Counts per minute[a] |
|---|---|---|---|---|
| | Simazin application | Water application | | |
| Exp. 7 | Surface | Surface | Corn | 23 |
| | Surface | Surface | Cotton | 595 |
| | Surface | Subirrigation | Corn | 6 |
| | Surface | Subirrigation | Cotton | 10 |
| Exp. 8 | Incorp. | Surface | Corn | 36 |
| | Incorp. | Surface | Cotton | 157 |
| | Incorp. | Subirrigation | Corn | 8 |
| | Incorp. | Subirrigation | Cotton | 20 |

[a]No cucumber lived long enough to provide a 1 x 3 cm sample and hence is not included.

radioactive carbon dioxide. More radioactivity was found in the leaves of the plants in Experiment 7 where the simazin was applied to the surface than in Experiment 8 which used the same soil but mixed the simazin throughout. This decreased absorption probably resulted primarily from two things. First, some simazin was removed by the plants in the first experiment and second, the mixing process brought the simazin into contact with more clay colloids where adsorption could occur. The autoradiograms made from these two experiments showed the same leaf accumulation patterns for plants grown in the soil as for those grown in nutrient solution.

The effect of various treatments on the foliar absorption of simazin are given in Table 4. It has been reported that simazin is not effective as a foliar spray. This could be the result of either a failure in absorption or translocation. The limitation to absorption would be expected to be the cuticle. Failure to translocate downward might be because the material is not phloem mobile and moves only in the xylem with the transpiration stream.

*Table 4.* The effect of various treatments on the foliar absorption of simazin by corn, cotton, and cucumber.

| Experiment number | Treatment | Plant | Counts per minute | |
|---|---|---|---|---|
| | | | Leaf above treated leaf | Leaf below treated leaf |
| Exp. 9 | Roots in 5% NaCl sol. for 0.5 hour | Corn | 0 | —[a] |
| | Roots in nutrient solution | Corn | 0 | — |
| Exp. 10 | Roots in 5% NaCl sol. for 1.33 hour | Corn | 0 | — |
| | Roots in nutrient solution | Corn | 0 | — |
| Exp. 11 | Sanded | Corn | 0 | 0 |
| | Not sanded | Corn | 0 | 0 |
| | Sanded | Cotton | 144 | 66 |
| | Not sanded | Cotton | 0 | 0 |
| | Sanded | Cucumber[b] | 773 | 375 |
| | Not sanded | Cucumber[b] | 134 | 18 |

[a]No radioassay made.
[b]Leaves in simazin solution died.

In Experiments 9 and 10 an attempt was made to reverse the transpiration stream in corn by having the roots in a strong salt solution and the leaves in simazin solution of low osmotic pressure. No simazin was detected in the leaves in either experiment. A supplementary experiment established that simazin could be moved in either direction in an excised segment of the corn leaf by reversing the absorbing and transpiring ends. A second supplementary experiment used split root systems of corn and cucumber. If simazin was applied to one half of the root system, radioactivity was detectable in the other half in 24 hours, but the amount was relatively small.

In Experiment 11 simazin was applied to leaves whose surface had been lightly sanded to break the cuticle and to unsanded plants. All sanded leaves absorbed appreciable amounts of simazin in 48 hours. The radioactivity was detectable both in the leaves above and below the treated leaves in cotton and cucumber. Radioactivity in corn was present only in the treated leaf, but was present beyond the actual site of simazin application. When the leaves were not sanded, no activity was found in the leaf above or below the treated one, except in cucumber where there was a small amount. This may have been partially associated with the death of these leaves in the simazin solution. No other leaves were killed. These experiments indicate that the cuticle is a rather effective barrier to the absorption of simazin. Simazin will move both upward and downward in the plant so it may be slightly phloem mobile as well as xylem mobile. Simazin, or the $C^{14}$-labeled degradation products, did not move as readily in corn as in cucumber. Cotton appeared to be intermediate in this respect.

In Experiment 12 the chloroform-soluble radioactive material was compared with the total in the leaves of corn, cotton, and cucumber which were grown in radioactive simazin solution. Since Roth (5) established that corn sap degraded simazin and since this is a postu-

lated mechanism of resistance, it was decided to determine what fraction of the radioactivity in the various plant leaves was simazin or other chloroform-soluble compounds. The average percentages found were: corn 3, cotton 23, and cucumber 64. These averages were from 3 separate determinations and the differences are highly significant, but the values are only relative since the counts were not corrected for self absorption. The leaf samples weighed 1.9 ± 0.3 mg/cm² and thus self absorption would be expected to be approximately 25 per cent. In a parallel test it was found that about 90 per cent of the simazin added to a ground leaf sample could be recovered by the chloroform extraction procedure used in this experiment.

## SUMMARY

1. Carbon$^{14}$-labeled simazin, 2–chloro–4,6–bis(ethylamino)–*s*–triazine, was used to study the absorption and translocation of this compound by the roots and leaves of corn, cotton, and cucumber grown in nutrient culture and in soil. Radioassay was made with a gas-flow counter assembly and with autoradiographs.

2. Simazin was very toxic to cucumber, of intermediate toxicity to cotton, and of slight toxicity to corn. The characteristic toxicity symptoms in cucumber and in cotton were marginal necrosis of the leaf followed by eventual collapse and death of the whole plant. The only toxicity symptom in corn was stunting, which was noted after a prolonged period in a nearly saturated solution of simazin.

3. Simazin, or a biologically active C$^{14}$-labeled degradation product, accumulated in the edges of cucumber leaves where necrosis first occurred. High areas of radioactivity in cotton were the lysigneous glands of the stem and leaves and the edges of the leaves. Radioactivity was rather evenly distributed throughout the corn plant. The distribution patterns were verified using the freeze-dry technique.

4. The absorption and translocation of simazin from the soil followed the same pattern as from nutrient culture. More simazin was absorbed from soil that received simulated rainfall than from subirrigated soil.

5. Simazin or C$^{14}$-labeled degradation products moved from the roots to the leaves of cucumber in less than 0.5 hour. The radioactivity was first confined to the veins, but after 8 hours commenced accumulating in the leaf margin and in the interveinal areas.

6. Simazin moved readily into the roots of all three plants. Almost no absorption occurred through the intact leaves, however, simazin did enter when the cuticle was broken.

7. Chloroform-soluble C$^{14}$-labeled compounds, simazin and/or degradation products, accounted for approximately half of the total radioactivity in cucumber leaves, one fourth of that in cotton, and one twentieth of that in corn.

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# Control of Certain Aquatic Weeds in Missouri Farm Ponds

CHARLES R. WALKER[1]

## INTRODUCTION

THE control of submersed aquatic weeds is a major problem in the management of Missouri fish ponds. Dense stands of aquatic vegetation in ponds cause serious crowding and stunting of fish populations. Recreational values are impaired by the physical interference of weeds with fishing and boating. Even more serious are the occasional partial or complete kills of fish caused by oxygen depletion as plants decay. These kills may occur either in summer or winter.

The improper use of inorganic fertilizers to increase fish production has complicated pond fish management. Many problems confronting this management practice have led several states to abandon fertilizer recommendations or further investigate its problems. Such a program of investigation has been pursued in Missouri during the past seven years. Direct broadcasting of fertilizer elements into water frequently produced undesirable side effects. Stimulation of aquatic weed growths resulted in many instances from the accumulation of fertilizer nutrients on the pond bottom (2). A new concept of artificial enrichment was developed during 1953 and 1954 (3). This was the continual addition of water soluble fertilizers and partially soluble commercial mixed grades and superphosphate fertilizer by means of floating suspension devices.

## FERTILIZER FOR AQUATIC WEED CONTROL

The suspension devices were of two basic designs. One type was a floating platform constructed with an open top which gave free access of the water to the fertilizer (Figure 1). This platform, submersed about one foot below the water surface, was suspended by floats made of five-gallon cans. Superphosphate and high analysis mixed fertilizers were dispensed from this device. Another type of suspension device was used to distribute water soluble fertilizer (Figure 2). This was an inverted can in which air trapped in part of the can acted as a float which supported the can and its load of fertilizer. The sides of the can were perforated to allow the fertilizer to be mixed with water and to escape into the pond. Both the platforms and the cans were anchored, and enough of them were used to allow for an even distribution of fertilizer in the pond. One platform or five cans per surface acre provided satisfactory distribution. Water soluble fertilizers were also dispensed from 55-gallon barrels. The large containers were used in bodies of water more than one acre in area. One barrel per acre gave satisfactory coverage. These techniques were effective, gave desired results, and required less labor than other methods of applying fertilizer.

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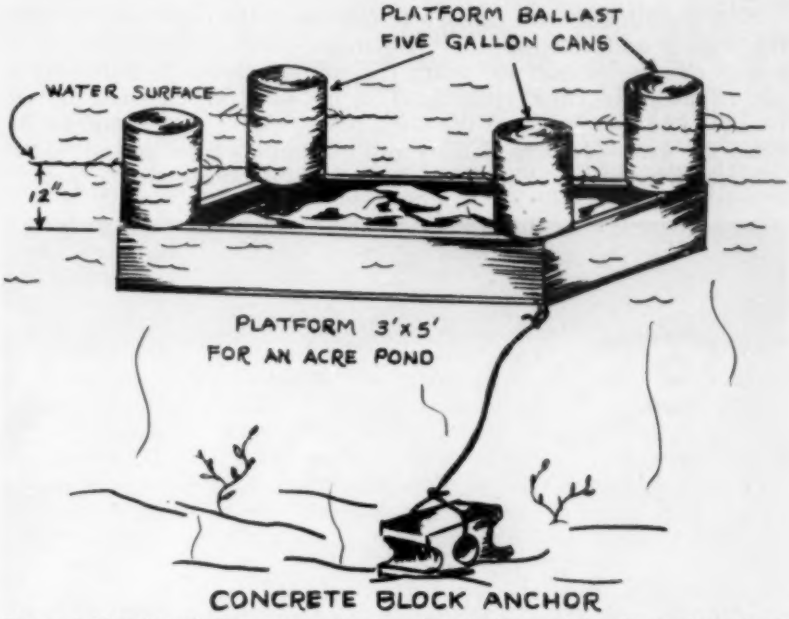


*Figure 1.* Floating platform type of suspension device used for dispensing mixed commercial fertilizers and superphosphates in fishing ponds to increase fish production.

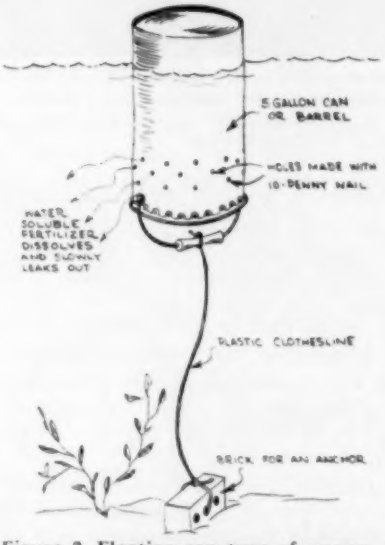


*Figure 2.* Floating can type of suspension device used for dispensing pelleted water-soluble fertilizers in fishing ponds to increase fish production and to control certain aquatic weeds.

New techniques were devised to overcome the difficulties of plot replication and controls that jeopardize field investigations. One useful new technique was that of dividing a pond in half with a vinyl plastic curtain (Figure 3). This provided an effective barrier between the two halves of the same pond. Use of the curtain facilitated the study of water fertility and fish populations, and provided a method by which reliable results could be obtained.

*Figure 3.* The barrier used in dividing a pond in half for the purpose of obtaining direct comparison of fishery management practices. The vinyl or polyethylene sheeting is suspended from styrofoam floats and anchored to the bottom with sandbags to effect the seal.

To control submersed aquatic weeds by fertilizer, applications must be started in April. The control achieved by using superphosphate and mixed commercial fertilizers dispensed from the floating platform was effected by the shading afforded by the plankton bloom produced. However, these fertilizers did not always produce a plankton bloom. Many times they stimulated the growth of undesirable filamentous algae instead of the plankton species. The initial application of 100 pounds of 0–46–0 or 200 pounds of 8–24–8 per acre was made from the floating platform. Subsequent applications were made at half this rate when the supply was so depleted as to allow plankton turbidity to diminish.

Water soluble ammonium phosphate fertilizer in a pelleted 16–20–0 formulation was found to be superior to other fertilizers for the control of submersed weeds. Its herbicidal action was different from that described above. Instead of killing weeds only by shading, the water soluble fertilizer also demonstrated a direct toxicity of the ammonium salt to weeds adjacent to the suspension devices. Appli-

cation rates of 20 to 35 pounds of 16–20–0 per acre foot produced continual plankton blooms of unicellular algae and supported heavy populations of animal plankton. This was in contrast to 4–12–4, 8–24–8, 0–20–0 and 0–46–0 which were effective only in producing periodic plankton blooms. The best initial applications of 16–20–0 averaged slightly higher than 30 pounds per acre foot dispensed from four to five containers per surface acre. These suspension devices were recharged at a similar rate about three times during the course of the growing season, or whenever the turbidity diminished to the point that a shiny tin can lid could be seen at a depth of two feet.

The use of 16–20–0 water soluble ammonium phosphate fertilizer holds promise of increasing fish production and of controlling certain submersed aquatic weeds. Plants which this fertilizer has controlled in experimental ponds include pondweeds *(Potamogeton foliosus, P. filiformis, P. pectinatus, P. diversifolius)*, muskgrass *(Chara)*, water hyssop *(Bacopa rotundifolia)*, and certain filamentous algae *(Cladophora, Spirogyra, Hydrodictyon, Microspora, Rhizoclonium, Zygnema* and *Ulothrix)*. However, it must be pointed out that control of these aquatic weeds was difficult if fertilizer applications were started too late in the season or were allowed to lapse. One species of filamentous algae *(Pithophora)* could not be controlled by fertilization.

The particular fertilizer proven most satisfactory for clear waters prone to weed infestation was a water soluble 16–20–0 formulation of ammonium phosphate. Partially soluble mixed commercial grades and superphosphate fertilizers were most effective in waters characterized by clay turbidity on soils with high lime requirements. However, water soluble 16–20–0 was found to be superior to platform dispersed superphasphate type fertilizers in the production of fish and fish food organisms (4). One distinct advantage was the possibility of controlling certain submersed aquatics. Another quality which should be pointed out was the production of a continuous plankton "bloom" of unicellular algae which supported dense animal plankton populations. This was not generally true of other types of fertilizers applied to the floating platform or broadcasted directly to the water. Superphosphates and mixed commercial fertilizers applied in this manner also produced blue-green algae which have caused fish mortalities during heavy concentration or "bloom" conditions. Some of these blue-green algae have been reported to be toxic (1).

## HERBICIDES FOR AQUATIC WEED CONTROL

Laboratory screening tests for new aquatic herbicides were made in the laboratory by common bioassay methods. However, testing these chemicals under field conditions presented difficulties. Toxicities to both plant and animal life may be modified by the natural environment. The results of our initial field experiments were often difficult to evaluate because of inadequate controls. To overcome this difficulty another useful application of the plastic curtain was developed (Figure 4). Small enclosures were constructed along the

*Figure 4.* Aquatic weed control enclosures constructed of vinyl or polyethylene sheeting suspended from styrofoam floats and anchored to the bottom with sandbags to effect a seal.

shore by driving two stakes at the outer edge of the plot and suspending the plastic sheet from styrofoam floats. The bottom of the plastic sheet was buried to a depth of three inches to seal off the plot.

Granular or pelleted herbicides have some important advantages over powdered or liquid formulations. They are easier to handle and they eliminate the need of special equipment for application. Low solubility, density and longevity of herbicidal contact are desirable qualities which increase the effectiveness of the herbicide in aquatic weed control. Low toxicity to fish and aquatic organisms is another important consideration in selecting herbicides for aquatic use.

Two herbicides, which passed laboratory screening for toxicity, were used in plastic enclosures in an attempt to evaluate their effect on pondweeds *(P. americanus,* and *P. foliosus),* muskgrass *(Chara)* and cattails *(Typha latifolia)* which grew in dense stands in the test areas. The pond and the enclosures were stocked with fingerling largemouth bass *(Micropterus salmoides),* bluegill sunfish *(Lepomis macrochirus),* and channel catfish *(Ictalurus punctatus).* Bottom dwelling insects which serve as fish food were sampled by the Peterson dredge method and studied both qualitatively and quantitatively.

Enclosure A received a 100 pounds per acre application of a pelleted formulation of 2–chloro–4,6–bis(ethylamino)–*s*–triazine (simazin) containing 10 percent active ingredient. Enclosure B received a

44 pound per acre treatment of a pelleted formulation containing 20 percent sodium 2,4–dichlorophenoxyacetate (2,4–D) and 5 percent sodium 2,2–dichloropropionate (dalapon). Both of these chemical applications were made on the aforementioned submersed aquatic weeds at the seed development stage. This was the time of their densest growth, when control with arsenicals was most difficult. Cattails were starting to develop heads.

Observations for phytotoxicity were negative during the first week and did not become marked until the 4th week following application. Simazin treated plot A showed phytotoxicity to all submersed vegetation, varying from chlorotic condition of the emergent leaves of *P. americanus* to the burned and rotting of leaves and stems of all the other submersed species. Simazin did not appreciably affect the condition on the cattails. Enclosure B, which received the sodium salts of 2,4–D and dalapon, showed burning of the leaves of *P. americanus* and some in cattails, but no obvious effect on *Chara,*

*Table 1.* The comparative production of fish food organisms in plastic enclosures treated with two pelleted herbicides. Samples were taken with a Peterson dredge.

| Aquatic organism | Number per square foot | | |
|---|---|---|---|
| | Enclosure A[a] | Enclosure B[b] | Control |
| Snails (*Physidae*) | 8.0 | 5.7 | 3.0 |
| Aquatic earthworms (*Oligocheata*) | 64.3 | 133.3 | 55.0 |
| Water bugs (*Coleoptera*) | 3.0 | — | — |
| Caddis fly larvae (*Trichoptera*) | 0.3 | 0.3 | 1.0 |
| Dragon fly larvae (*Odonata*) | 0.7 | — | — |
| Horse fly larvae (*Tabanidae*) | 11.6 | 5.7 | 1.7 |
| Phantom midge larvae (*Chaoborinae*) | 168.7 | 7.3 | 0.6 |
| Common midge larvae (*Tendipendidae*) | 3.0 | 0.3 | 2.0 |
| Biting midge larvae (*Ceratopogonidae*) | — | — | 9.0 |
| Total number per sq ft | 259.6 | 153.3 | 72.3 |
| Total weight in grams[c] | 1.35 | 0.85 | 0.80 |

[a]10% 2–chloro–4,6–bis(ethylamino)–*s*–triazine pellets at 100 lb/A.
[b]20% sodium 2,4–dichlorophenoxyacetate and 5% sodium 2,2–dichloropropionate pellets at 44 lb/A.
[c]These data include snails.

*P. americanus,* or on a recent growth of filamentous algae *(Chladophora* and *Spirogyra).* This experiment proved these materials were not toxic to the fish or the fish food organisms. The results presented in the analysis of the bottom fauna show the marked variation in species composition, but give no indication of deleterious effects of the herbicides (Table 1). A plankton bloom also occurred in the simazin-treated enclosure following the mortality of the pondweeds in the fourth week of observations.

## SUMMARY

1. Distributing water soluble 16–20–0 fertilizer from special floating distributors has given effective control of many submersed aquatic weeds by direct toxicity as well as producing a continuous plankton bloom.

2. Distribution 0–46–0, 8–24–8, or other mixed fertilizer from

floating platforms was superior to broadcast distribution in the water, but inferior to 16–20–0 as above.

3. The technique of dividing a pond in two, or making several small enclosures, with vinyl plastic sheets supported by styrofoam floats and buried at the bottom, was valuable for both fertilizer and herbicide studies.

4. Pelleted simazin and a dalapon–2,4–D mixture did not injure fish of fish food species. Simazin was effective in controlling most submerged weeds.

5. Pelleted herbicides have been more effective and longer-lasting than liquid formulations.

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# Chemical Weed Control in Seedling Alfalfa
# II. Control of Broad-Leaved Weeds[1]

PAUL F. SAND and M. K. MCCARTY[2]

LEGUMINOUS crops for hay, seed, pasture or soil improvement occupy a large portion of the total crop acreage. Plantings of legumes, particularly alfalfa, are often maintained long after production has dropped below an economic level. The reason may be reluctance of farmers to attempt establishment of new stands. In areas where fall seeding is possible but where mosture is often scant, spring seedings with the attendant hazard of annual weeds, must be relied upon for establishment of new stands.

Until a few years ago, the main cultural aid in establishment was mowing to decrease the competition of the annual weeds for moisture, light and nutrients. Recent research (4) indicated the possibility of using chemical methods for the reduction of hazards from certain annual grasses. There remains the problem of removing the broad-leaved weeds from the legume seedings.

## REVIEW OF LITERATURE

Early attempts at removing broad-leaved weeds from seedling alfalfa with chemicals usually relied upon contact herbicides (5). Though contact herbicides were successful under some conditions, damage was sustained at times by the legumes or effectiveness was reduced. Santelmann and Willard (6) used MCPA (2–methyl–4–chlorophenoxyacetic acid) and 2,4–D (2,4–dichlorophenoxyacetic acid) at low rates (1/8 to 1 lb/A) on legume seedings. At early stages of growth when the weeds had not produced a well defined canopy, rates above 1/8 lb/A damaged the legume stand. Regardless of canopy development at time of treatment, the ester form of 2,4–D caused damage to the legumes, ranging from moderate with 1/8 lb/A to severe at 1/2 lb/A.

Brown (1,2), in 1953 and again in 1954, treated new seedings of alfalfa and sweetclover with 2 to 6 oz/A of 2,4–D and MCPA. Applications were made at four stages of growth, ranging in height from 1–2 inches to 7–9 inches. Damage was greater on sweetclover than on alfalfa at all rates and stages, with the alfalfa showing the least damage at the early stages of growth.

Synerholm and Zimmerman (8) reported in 1947 on the synthesis and growth regulating properties of seven phenoxyalkylcarboxylic acids with side chains ranging in length from 2 to 8 carbon atoms. They observed that the homologues having an even number of carbon atoms were active in a tomato leaf epinasty test while the ones having odd numbers of carbon atoms were inactive. They

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proposed that beta-oxidation within the plant converted the longer chains to the active 2-carbon homologue. Wain and Wightman (10) confirmed this theory in 1954 after detailed laboratory experimentation. Wain (9) in 1955 suggested the possibility of utilizing the differences in enzymatic activity of various plants as an additional selective tool for weed control. Many of the legumes seemed to lack the ability to make the conversion from the inactive to the active form.

Willard and Rhykerd (11), in 1955, reported work on alfalfa and red clover with two new materials similar to 2,4–D but with a 4-carbon side chain. These were 2–methyl–4–chlorophenoxybutyric acid and 2,4–dichlorophenoxybutyric acid, 4–(MCPB) and 4–(2,4–DB), respectively. Applications were made at 1 and 2 lb/A to new seedings of alfalfa and red clover that were 4 to 6 inches high. Neither chemical injured red clover at either rate. Neither rate of 4–(2,4–DB) injured alfalfa but the heavier rate of 4–(MCPB) caused some injury.

Shaw and Gentner (7) in 1957 reported screening studies utilizing variously substituted members of the phenoxyacetic, phenoxypropionic and phenoxybutyric acids on several plant species. The potential use of 4–(2,4–DB) and 4–(MCPB) for the post-emergence control of broad-leaved weeds in legume establishment work was emphasized. Kherkin and Peters (3) treated seedlings of alfalfa with 2,4–D, 4–(2,4–DB) and 4–(MCPB) at rates up to 3 lb/A. All rates (0.2, 0.4 and 0.8 lb/A) of 2,4–D were toxic to alfalfa whereas no toxicity from 4–(2,4–DB) was exhibited up to 3 lb/A. There was an indication of toxicity of 4–(MCPB) at the higher rates on alfalfa.

## MATERIALS AND METHODS

Ranger alfalfa was seeded on Sharpsburg silty clay loam on the Agronomy farm at Lincoln, Nebraska, on April 18, 1956, and on April 17, 1957. Ten pounds per acre of alfalfa was drilled with a mixture of about 10 percent weed seed, mainly green and yellow foxtail. Forty pounds per acre of $P_2O_5$ was applied at the time of seeding. Plots seven feet wide and twenty-one feet long were established in a randomized complete block design soon after the alfalfa was planted. Each treatment was replicated four times.

The same chemicals and rates were used each year. They were 4–(2,4–DB) butyl ester, 4–(2,4–DB) dimethylamine, 4–(MCPB) butyl ester and 2,4–D dimethylamine, all applied at rates of 1/2 and 1 lb/A. Chemicals were applied in 40 gallons of water per acre with a hand sprayer which used carbon dioxide to maintain a constant pressure. A 6-foot strip through each plot was sprayed by passing the spray boom over it once. The boom was covered with a hood to prevent drift to adjacent plots.

Herbicidal treatments were applied on June 1, 1956, and on June 5, 1957. The height of alfalfa at the time of treatment in 1956 was 4 inches and in 1957, 3 to 6 inches. The main broad-leaved weeds in the experimental area in 1956 were pigweed *(Amaranthus retroflexus* L.), kochia *(Kochia scoparia* (L.) Schrad), and scattered patches of annual smartweed *(Polygonum pennsylvanicum* (L.) Small), which

were 3 to 4 inches tall at the time of treatment. Annual grasses, green foxtail *(Setaria viridis* (L.) Beauv.) and yellow foxtail *(Setaria lutescens* (Weigel) F. T. Hubbard), were 2 to 5 inches tall when treatments were applied. In 1957, the broad-leaved weeds in the experimental area were kochia, pigweed, and annual smartweed, with widely scattered plants of velvet leaf *(Abutilon theophrasti* Medic.) and lambsquarters *(Chenopodium album* L.). Most of the weeds were 1 to 4 inches tall at the time of treatment but occasional plants were 6 to 8 inches tall. Grasses were green and yellow foxtail and stinkgrass *(Eragrostis cilianensis* (All.) Link.), 2 to 4 inches tall.

Treatments were evaluated by making stand counts and obtaining separate vegetative yields of alfalfa and weeds. Stand counts of alfalfa stems and broad-leaved weeds were made from five 2 x 4-foot quadrats in each plot the first week in July. Since weedy grasses did not appear to be affected by treatment, stand counts for them were taken from one 2 x 4-foot quadrat. Yields were obtained from one 2 x 4-foot quadrat early in July when the alfalfa was in the bud stage. Clippings were separated into three parts; alfalfa, broad-leaved weeds and weedy grasses. These were oven-dried, weighed and converted to a pounds per acre basis.

## RESULTS AND DISCUSSION

Data in Tables 1 and 2 show that numbers of alfalfa stems and weeds were somewhat higher in 1956 than in 1957. Even though this difference existed, the treatment effects were very similar during the 2 years. In 1956, 2,4–D amine at 1 lb/A reduced the stem count of alfalfa to the greatest extent (Table 1). It was followed by 1 lb of 4–(MCPB) ester and 1/2 lb of 2,4–D. In 1957, the only treatment that had significant detrimental effect on alfalfa stand was 2,4–D amine at the rate of 1 lb/A. Stem counts of alfalfa treated with 4–(2,4–DB) ester and amine showed increases over the check in both

*Table 1.* The effect of 4–(2,4–DB), 4–(MCPB) and 2,4–D on stand and yield of Ranger alfalfa. Harvests were made at the early bud stage of the alfalfa.

| Treatment | Rate lb/A | Alfalfa count Stems in 40 sq. ft. | | | Alfalfa yield Pounds dry matter/A. | | |
|---|---|---|---|---|---|---|---|
| | | 1956 | 1957 | Av. | 1956 | 1957 | Av. |
| 4–(2,4–DB) amine | ½ | 1008 | 649 | 828 | 495** | 696 | 595 |
| | 1 | 969 | 672 | 820 | 492** | 1416** | 954 |
| 4–(2,4–DB) ester | ½ | 988 | 714 | 851 | 525** | 1407** | 766 |
| | 1 | 950 | 541 | 745 | 387** | 1095** | 741 |
| 4–(MCPB) ester | ½ | 817 | 548 | 682 | 333 | 396 | 364 |
| | 1 | 718* | 508 | 613 | 285 | 609 | 447 |
| 2,4–D amine | ½ | 746* | 486 | 616 | 228 | 705 | 466 |
| | 1 | 295** | 341* | 218 | 57** | 360 | 208 |
| Check | | 892 | 574 | 733 | 288 | 342 | 315 |
| Standard error of the mean difference | | 70 | 97 | | 34 | 230 | |

*Difference from the check exceeds the .05 level of significance.
**Difference from the check exceeds the .01 level of significance.

*Table 2.* The effect of 4–(2,4–DB), 4–(MCPB) and 2,4–D on stand and yield of broad-leaved weeds in a spring seeding of Ranger alfalfa. Harvests were made at the early bud stage of the alfalfa.

| Treatment | Rate lb/A | Weed counts Plants per 40 sq. ft. | | | Weed yields Pounds dry matter/A. | | |
|---|---|---|---|---|---|---|---|
| | | 1956 | 1957 | Av. | 1956 | 1957 | Av. |
| 4–(2,4–DB) amine | ½ | 56** | 29** | 42 | 264** | 939** | 601 |
| | 1 | 23** | 20** | 21 | 78** | 423** | 250 |
| 4–(2,4–DB) ester | ½ | 72** | 9** | 40 | 240** | 351** | 295 |
| | 1 | 20** | 5** | 12 | 81** | 117** | 99 |
| 4–(MCPB) ester | ½ | 73** | 45 | 59 | 648** | 2757 | 1702 |
| | 1 | 76* | 42 | 59 | 518** | 600** | 559 |
| 2,4–D amine | ½ | 76* | 38 | 57 | 537** | 966** | 751 |
| | 1 | 48** | 24** | 36 | 57** | 573** | 315 |
| Check | | 140 | 68 | 104 | 2023 | 4188 | 3105 |
| Standard error of the mean difference | | 23 | 9 | | 297 | 728 | |

*Difference from the check exceeds the .05 level of significance.
**Difference from the check exceeds the .01 level of significance.

years, but these increases were not statistically significant. A few plants in the plots treated with 1 lb/A of these two chemicals showed curvature several days after application, but they quickly outgrew these effects.

Yields of alfalfa treated with both rates of 4–(2,4–DB) amine and ester showed increases over the check each year. Although these increases in yield were due to the reduction in competition from broad-leaved weeds, the amounts were held down by the attendant increases in yield of annual grasses. Alfalfa yield was not depressed as much by 1 lb/A of 2,4–D amine in 1957 as it was in 1956.

Figures 1 and 2 compare the effects of 1 lb/A of 4–(2,4–DB) ester with 1 lb of 2,4–D amine, respectively. The alfalfa plants treated with 4–(2,4–DB) ester looked normal, but treatment with 2,4–D amine reduced stand and stunted the remaining plants.

The numbers of broad-leaved weeds (Table 2) were reduced significantly below those in the check. However, the numbers of broad-leaved weeds did not show a true picture of the degree of control because all weeds that were green were counted even though some of them were severely stunted. Consequently, yields rather than counts gave a more accurate picture of broad-leaved weed control. Yields of broad-leaved weeds were reduced by all treatments. In 1956, 4–(2,4–DB) ester and amine were nearly equal in effectiveness but in 1957, the ester formulation was more effective than the amine in reducing the yield of broad-leaved weeds. The 1 lb rate was more effective than the 1/2 lb rate of both chemicals, but the 1/2 lb/A rate of ester gave satisfactory weed control each year. Both formulations of 4–(2,4–DB) were about as effective as the amine salt of 2,4–D. However, 4–(MCPB) ester was the least effective chemical in the experiment against broad-leaved weeds.

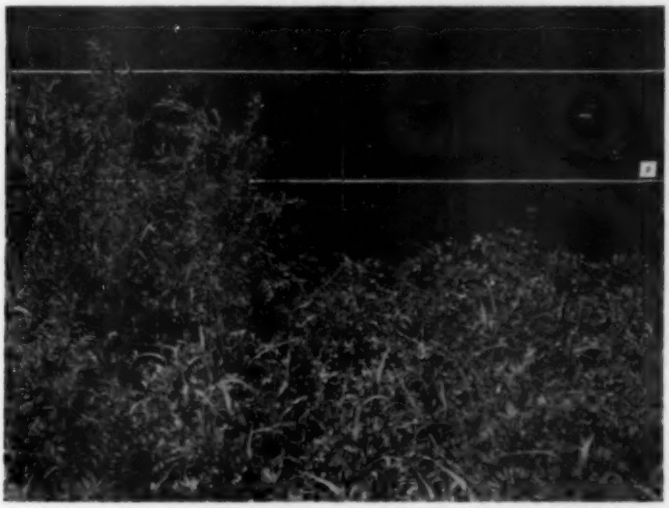

*Figure 1.* Broad-leaved weed control in spring seeded alfalfa. One lb/A 4-(2,4-DB) ester on right and check on left. Treated June 1, 1956. Photo July 9, 1956.

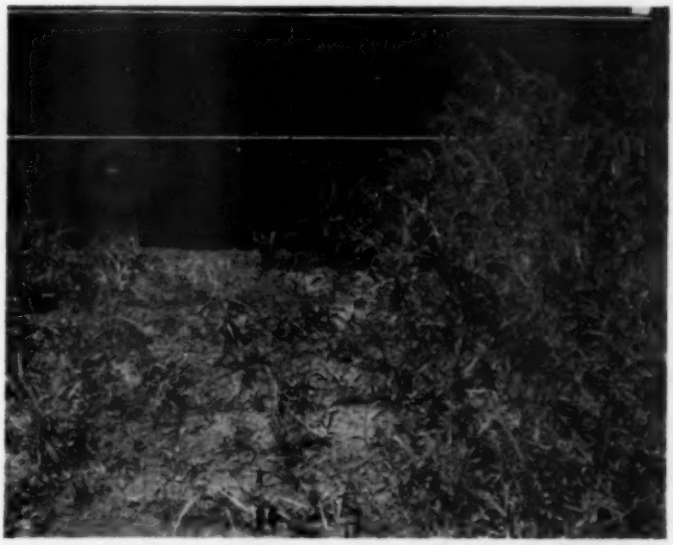

*Figure 2.* Broad-leaved weed control in spring-seeded alfalfa. One lb/A 2,4-D amine on left, check on right. Treated June 1, 1956. Photo July 9, 1956.

The weedy grasses were not affected directly by any of the chemicals. Numbers of weedy grass plants (Table 3) did not vary much from the check, but their yields were increased almost proportionately to the degree of control of broad-leaved weeds. Grass yields were higher from all treatments than from the check, but the differences were not statistically significant.

*Table 3.* The effect of 4–(2,4–DB), 4–(MCPB) and 2,4–D on stand and yield of weedy grasses in a spring seeding of Ranger alfalfa. Harvests were made at the early bud stage of the alfalfa.

| Treatment | Rate lb/A | Weedy grass counts Plants per 8 sq. ft. | | | Weedy grass yields Pounds dry matter/A. | | |
|---|---|---|---|---|---|---|---|
| | | 1956 | 1957 | Av. | 1956 | 1957 | Av. |
| 4–(2,4–DB) amine | ½ | 38 | 30 | 34 | 855 | 900 | 922 |
| | 1 | 59 | 18 | 38 | 1182 | 1683 | 1432 |
| 4–(2,4–DB) ester | ½ | 70 | 17 | 43 | 999 | 1461 | 1230 |
| | 1 | 66 | 15 | 40 | 1107 | 681 | 894 |
| 4–(MCPB) ester | ½ | 41 | 20 | 30 | 981 | 1035 | 1008 |
| | 1 | 60 | 41 | 50 | 816 | 1089 | 952 |
| 2,4–D amine | ½ | 42 | 21 | 31 | 1002 | 1077 | 1039 |
| | 1 | 48 | 25 | 36 | 1197 | 1209 | 1203 |
| Check | | 42 | 26 | 34 | 555 | 582 | 568 |
| Standard error of the mean difference | | 11 | 8 | | 231 | 481 | |

## SUMMARY

The dimethylamine and the butyl ester of 4–(2,4–DB) were found to be satisfactory for controlling broad-leaved weeds in seedling alfalfa. Neither chemical had any detrimental effect on Ranger alfalfa at 1/2 or 1 lb/A. Alfalfa forage yields were increased by the reduction of competition from the broad-leaved weeds. The ester form of 4–(2,4–DB) was somewhat more effective than the amine form in one of the two years and both forms gave more effective weed control than 4–(MCPB) ester. The 4–(MCPB) ester was also injurious to the alfalfa.

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# Logarithmic Sprayer Evaluations of Herbicides in Horticultural Crops

L. L. Danielson and Robert E. Wester[1]

The logarithmic, or variable-dosage, sprayer described by Pfeiffer, Brunskill, and Hartley (4) for use in experimental field plot studies appears to offer a means of materially reducing the time and space required to conduct field evaluations of herbicides in horticultural crops. The experiments described herein were conducted to determine the conditions necessary for the successful use of the sprayer in evaluations of this type.

An experimental evaluation of EPTC [ethyl N,N–di–*n*–propylthiolcarbamate] alone, and CDEC (2–chloroallyl diethyldithiocarbamate) in combination with CIPC [isopropyl N–(3–chlorophenyl)-carbamate] was conducted on a series of vegetable greens, salad, and cole crops.

## Principles of Construction and Operation of the Sprayer

The sprayer used in these studies was the Chesterford Logarithmic Sprayer Mark III[2] mounted on a jeep equipped with 4-wheel drive, a governor, and a wheel speedometer as shown in Figure 1. Modifi-

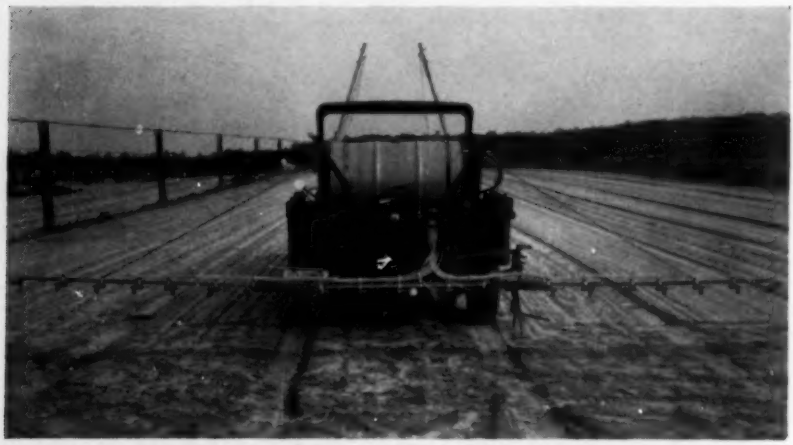

*Figure 1.* The Chesterford Logarithmic Sprayer Mark III mounted on a jeep, as used in the 1957 experimental studies conducted at Beltsville, Maryland.

cations of the original sprayer and the methods of using the equipment and interpreting results have been described in detail by Brunskill and others (1,2,3).

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The logarithmic sprayer will apply a logarithmic rate pattern of a selected range of a chemical on a pre-determined area in the field. Combinations of chemicals may also be applied in such a manner that a descending concentration gradient of one chemical is produced simultaneously with an ascending concentration gradient of a second chemical. The sprayer may also be used as a conventional sprayer to apply a constant treatment rate. Permutations and combinations of the individual methods of application possible with this sprayer provide the means for studying a wide range of problems.

The construction and operation of the logarithmic sprayer is dependent on the functioning of a concentrate chamber containing a mechanical agitator. A pipe leads from this chamber to a water supply tank. A second pipe leads from the chamber to a bronze gear pump which delivers the solution to the nozzles. Each nozzle is connected to a common manifold by a plastic tube. Each plastic tube is of the same length regardless of the location of the nozzle. This insures the arrival of the spray solution at all nozzles simultaneously. In use, the concentrate chamber is completely filled with the herbicide solution, prepared to give the highest desired rate, and the chamber is closed. When the pump begins to deliver concentrate solution to the nozzles, a negative pressure is established in the chamber and, as a result, fresh water is drawn in and intimately mixed with the solution by the mechanical agitator.

Pump pressure and rate of movement in the field are maintained constant throughout the treatment of each experimental series. In the present experiments, a speed of 3 miles per hour and a pressure of 40 pounds per square inch were maintained These conditions of operation delivered 33 gallons of spray per acre. Delivery rate is determined by speed, pressure, and nozzle aperture.

The valves on the sprayer model used in these experiments were so arranged that fresh water was sprayed until the sprayer approached the edge of the experimental plot. At this point, a steel marker tripped a lever which closed the fresh-water line to the pump and opened the line to the concentrate chamber. As a result, the first 4 yards of each plot were untreated as shown in Figure 2. At 6 yards from the tripping point, the logarithmic rate pattern began and dosage rates were halved at each 6.6 yards thereafter. This distance is referred to as the "half-dosage distance" and must be established for each sprayer. Experimental objectives of these studies were achieved by using plots 100 feet long.

## MATERIALS AND METHODS

The field area used in these experiments was equipped with overhead irrigation, which insured an adequate supply of water for normal crop development and herbicidal activity. The soil in the experimental area, a fine sandy loam, was prepared by plowing, disking, and harrowing with a Meeker harrow to provide a firm seed bed. Beds 4 feet wide were marked off before planting by running the sprayer through the field to establish wheel marks at intervals of 4 feet. This provided a settled track for the sprayer to follow

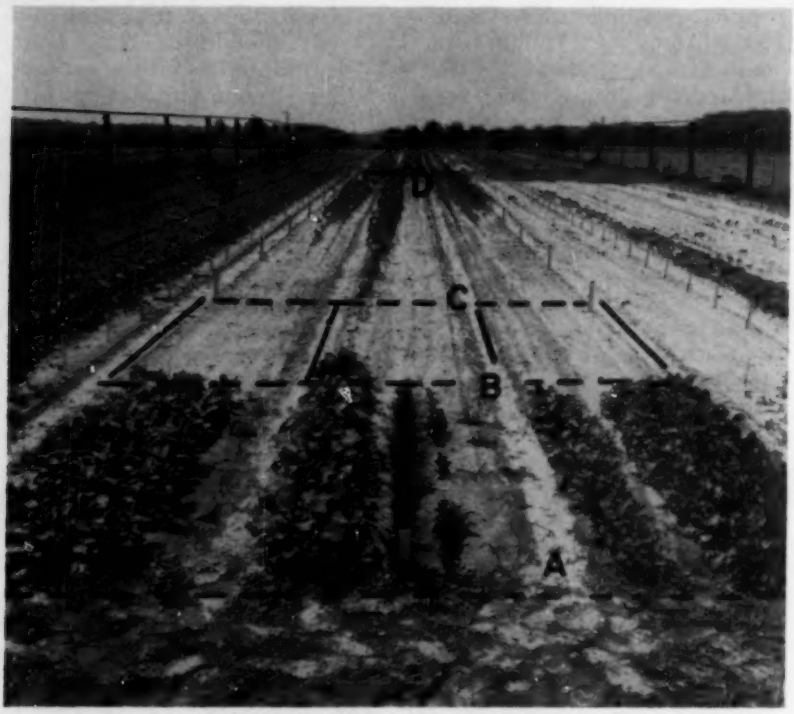


*Figure 2.* The series of vegetable greens, salad, and cole crops shown here were treated with a pre-emergence logarithmic sprayer application of a maximum of 10 pounds of EPTC per acre. Each plot consisted of 3 beds planted to 5 crops each, as seen here. The crops are, from left to right, celery, cabbage, collards, Brussels sprouts, endive; Hanover salad greens, cauliflower, ryegrass, lettuce, parsley; broccoli, spinach, mustard greens, kale, and turnip greens. Note the variation in crop response as the rate of application diminished. Planting and treatment date April 22, 1957. Harvest date June 6, 1957. See Figure 3.

during treatment and facilitated orderly hand planting. Preliminary herbicide evaluations were conducted with the logarithmic sprayer in 4 replications on a plot 3 beds wide and 100 feet long. The vegetable greens, salad, and cole crop varieties used in these studies are listed in Table 1. Mustard and ryegrass were included in all experimental plantings to serve as standard herbicide sensitive test species comparable to susceptible annual broadleaved weeds and grasses. The crops were randomized in the replicates of all treatment series. All herbicide applications were followed immediately, or within 24 hours, by an irrigation of approximately 1 acre-inch of water.

Results were determined by making crop-injury ratings, stand counts, and obtaining fresh weights. Data on logarithmic sprayer plots were collected from 1 yard of row centered on the half-dosage distance mark at each treatment level for each crop. The treatment levels are, therefore, ranges of treatment rates. These ranges have

*Table 1.* Binomials and varietal designations of crops used in experimental plantings.

| Crop | Binomial | Commerical variety |
|---|---|---|
| Broccoli | (*Brassica oleracea v. italica*) | Italian Green Calabrese |
| Brussels sprouts | (*Brassica oleracea v. gemmifera*) | Perfection |
| Cabbage | (*Brassica oleracea v. capitata*) | Late Flat Dutch |
| Cauliflower | (*Brassica oleracea v. botrytis*) | Early Snowball |
| Celery | (*Apium graveolens v. dulce*) | Golden Self Blanching |
| Collards | (*Brassica oleracea v. acephala*) | Vates |
| Endive | (*Cichorium endivia*) | Batavian Full Heart |
| Hanover salad greens | (*Brassica sp.*) | Early Hanover |
| Kale | (*Brassica oleracea v. acephala*) | Tall Green Scotch |
| Lettuce | (*Lactuca sativa*) | Great Lakes |
| Mustard greens | (*Brassica juncea*) | Southern Giant Curled |
| Parsley | (*Petroselinum crispum*) | Triple Curled |
| Ryegrass | (*Lolium multiflorum*) | Domestic |
| Spinach | (*Spinacea oleracea v. incymis*) | Old Dominion Blight Resistant |
| Turnip greens | (*Brassica campestris v. rapa*) | Seven Top |

been obtained from a nomograph and are presented in Table 2 for a 10-pound per acre logarithmic application. The rates for the 1 pound per acre CIPC logarithmic application can be determined from this table by moving the decimal one place to the left in column 2.

Optimum rates of application determined with the logarithmic sprayer were studied in subsequent randomized small plots 3 beds wide and 10 feet long. Four treatment levels were replicated 4 times. The number of crops studied varied from one experiment to another, the number depending on the seasonal requirements of each crop and the time of planting. The crops used are listed in the tables or figures in which the results are presented.

*Table 2.* Range of rates of application over 1 yard of row centered on half-dosage distance markers.[a]

| Yards from start | Rates of delivery in pounds per acre at successive half-dosage points and over corresponding sampled portions of row | |
|---|---|---|
| | At half-dosage markers | Over 1 yard distance sampled |
| 6.0 | 10.0 | 10.42–9.45 |
| 12.6 | 5.0 | 5.21–4.67 |
| 19.2 | 2.5 | 2.65–2.39 |
| 25.8 | 1.25 | 1.30–1.19 |
| 32.4 | 0.62 | 0.68–0.61 |

[a]Half-dosage distance = 6.6 yards. This is the distance the sprayer must travel to reduce the dosage rate by one-half. (See Brunskill (4) for further details.)

## RESULTS AND DISCUSSION

A survey of the large number of items of data collected in these studies indicated the need for a rapid method of assembling the information for evaluation. Accordingly, a "phytotoxicity index" was calculated for each crop at all levels of treatment examined for each chemical. This index is the average of the crop-injury rating, stand, and fresh weight expressed as percent of similar records from the control plots, except for ryegrass, for which fresh weight and

injury ratings only were used. For example, consider a hypothetical case in which a plant sample from a herbicide treated area had a visual injury rating of 70 percent as compared to samples from the untreated control area; a fresh weight equivalent to 40 percent as compared to the control; and a stand equivalent to 65 percent of the control. The calculation of the phytotoxicity index of these data would be as follows:

$$\text{Index} = \frac{70 + 40 + 65}{3} = 58.$$ The visual injury rating evaluated physical defects, abnormal colorations, and growth distortions due to herbicidal treatment. Fresh weights and stands represent 1 yard of row harvested. Careful observance of accepted experimental practices in collecting the data insured a level of accuracy suitable for the use of the index in the manner described here. The index values are presented in graphs as a further convenience in the comparison and evaluation of results.

*EPTC evaluations*

Preliminary evaluations of pre-emergence applications of EPTC were conducted on a group of vegetable greens, salad, and cole crops with the logarithmic sprayer. Results of the initial series of treatments applied immediately after planting are shown in a photograph (Figure 2) and in graphs (Figure 3) to demonstrate the method as applied to a single herbicide, namely EPTC at a maximum of 10 pounds per acre in a logarithmic application. In Figure 2, the area from A to B is an untreated control area. The area from B to C is a portion of the rate pattern that is not logarithmic. The area from C to D is the area covered by the logarithmic rate pattern of application and represents a range of 10 pounds per acre at C to approximately 0.62 pounds per acre at D. Note the variation in crop response as the rate of application diminished. The graphs in Figure 3 are arranged to present the results of the different treatment levels in the same order in which they appear in Figure 2.

Practical control of ryegrass was obtained with pre-emergence applications of 1.25 pounds of EPTC per acre and a number of the crops showed excellent growth at this rate (Figure 3).

Randomized replicated small-plot studies were organized based on the results obtained in the preliminary logarithmic sprayer applications of EPTC. Pre-emergence rates of EPTC employed in these confirmative studies were 1, 2, and 4 pounds per acre. Results are presented in Table 3. These data, which were analyzed statistically, corroborate the results obtained in the logarithmic sprayer studies.

*Evaluation of combination of CDEC and CIPC*

The logarithmic sprayer was used to study a changing ratio of CDEC to CIPC used in combination as pre-emergence treatments on a series of vegetable greens, salad, and cole crops. CDEC was applied at a constant rate of 1 pound per acre overall followed immediately by CIPC at 1 pound per acre in a logarithmic application.

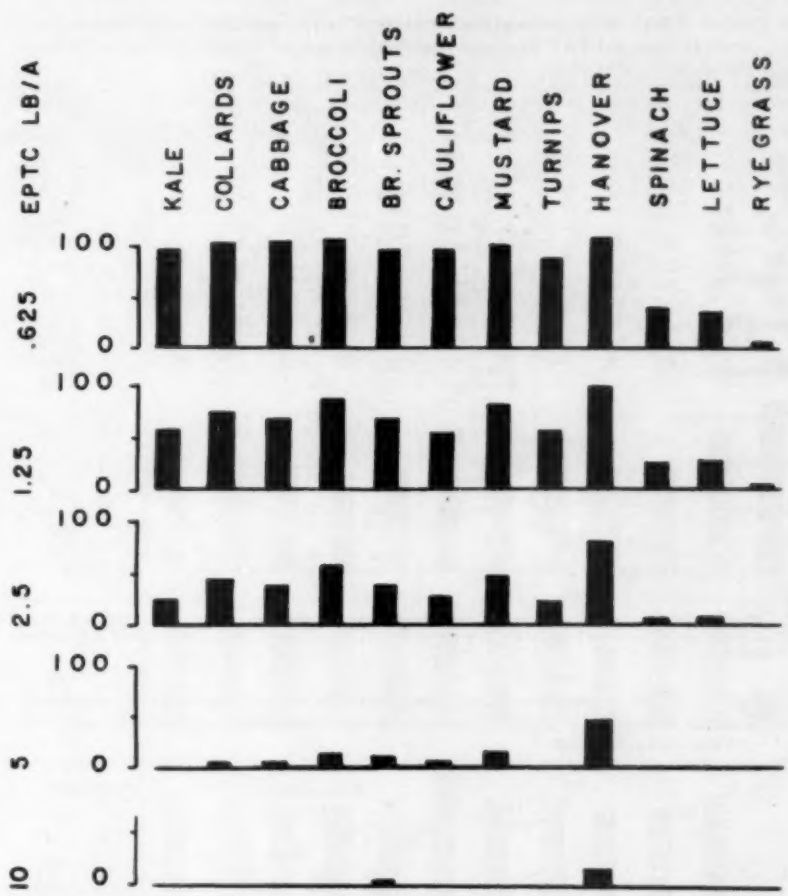


*Figure 3.* Results of the pre-emergence logarithmic sprayer application of 10 pounds of EPTC per acre on a series of vegetable greens, salad, and cole crops are shown expressed in terms of a phytotoxicity index for each crop at each treatment level range sampled. See Table 2 for range of rates over 1 yard of row sampled. A phytotoxicity index of 100 indicates normal growth and an index of 0 indicates complete kill. Planting and treatment date April 22, 1957. Harvest date June 6, 1957. See Figure 2.

This combination gave ratios of 1 pound of CDEC per acre to a wide range of levels of 1 pound and less of CIPC per acre. Results are presented in Figure 4. These data show that practical control of ryegrass was obtained with 1 pound of CDEC and 0.25 pound of CIPC without injury to the crops studied.

Subsequently, randomized replicated small-plot studies were organized on the basis of these preliminary logarithmic applications of CDEC in combination with CIPC. Rates of application employed were 1 pound of CDEC in combination with 0.25, 0.5, and 1 pound of CIPC per acre. Results are given in Table 4. These results con-

*Table 3.* Effect of pre-emergence "standard" non-logarithmic applications of several rates of EPTC on stand and fresh weight of certain vegetable greens, salad, and cole crops.*

| Crop | Item measured | EPTC—lb/A | | | | LSD | |
|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 4 | 5% | 1% |
| Kale | Stand | 41 | 19 | 1 | 2 | 9 | 13 |
| | Fr wt-gm | 488 | 170 | 11 | 16 | 127 | 181 |
| Collards | Stand | 40 | 44 | 30 | 13 | 8 | 11 |
| | Fr wt-gm | 743 | 875 | 469 | 99 | 239 | 339 |
| Cabbage | Stand | 43 | 33 | 17 | 5 | 16 | 22 |
| | Fr wt-gm | 424 | 301 | 191 | 53 | 163 | 232 |
| Broccoli | Stand | 52 | 47 | 27 | 10 | 21 | 30 |
| | Fr wt-gm | 650 | 528 | 238 | 57 | 297 | 422 |
| Mustard | Stand | 68 | 63 | 44 | 18 | 18 | 25 |
| | Fr wt-gm | 930 | 756 | 611 | 159 | 364 | 523 |
| Brussels sprouts | Stand | 35 | 21 | 13 | 3 | 16 | 22 |
| | Fr wt-gm | 335 | 179 | 57 | 10 | 185 | 263 |
| Cauliflower | Stand | 19 | 13 | 18 | 2 | 16 | 22 |
| | Fr wt-gm | 78 | 91 | 142 | 8 | 49 | 70 |
| Ryegrass | Fr wt-gm | 136 | 19 | 4 | 0 | 45 | 63 |
| Weed rating—percent control | | | | | | | |
| Annual grasses | | 0 | 46 | 43 | 88 | | |
| Broadleaved weeds | | 0 | 0 | 0 | 0 | | |

*Cole crops were in the early vegetative stage of growth at the time of harvest. Stands and weights of all crops are the average for 5 feet of row harvested. Planted July 1, 1957. Treated July 2; Harvested August 8.

*Table 4.* Effect of pre-emergence "standard" non-logarithmic applications of several rates of CDEC to CIPC on stand and fresh weight of vegetable greens, salad, and cole crops.*

| Crop | Item measured | Treatments—lb/A | | | | LSD | |
|---|---|---|---|---|---|---|---|
| | | CDEC—0<br>CIPC—0 | 1<br>0.25 | 1<br>0.5 | 1<br>1 | 5% | 1% |
| Kale | Stand | 36 | 31 | 35 | 39 | 11 | 16 |
| | Fr wt-gm | 468 | 648 | 675 | 525 | 276 | 393 |
| Collards | Stand | 37 | 43 | 44 | 49 | 11 | 16 |
| | Fr wt-gm | 965 | 1147 | 1103 | 1040 | 287 | 408 |
| Cabbage | Stand | 35 | 43 | 40 | 36 | 34 | 48 |
| | Fr wt-gm | 443 | 555 | 623 | 495 | 192 | 273 |
| Broccoli | Stand | 46 | 62 | 50 | 49 | 15 | 22 |
| | Fr wt-gm | 643 | 768 | 805 | 623 | 253 | 360 |
| Mustard | Stand | 60 | 64 | 64 | 63 | 10 | 14 |
| | Fr wt-gm | 1118 | 1470 | 1473 | 1153 | 265 | 377 |
| Brussels sprouts | Stand | 27 | 26 | 27 | 28 | 9 | 13 |
| | Fr wt-gm | 330 | 228 | 303 | 283 | 196 | 279 |
| Cauliflower | Stand | 23 | 23 | 10 | 21 | 9 | 12 |
| | Fr wt-gm | 149 | 124 | 138 | 96 | 100 | 143 |
| Ryegrass | Fr wt-gm | 153 | 0 | 0 | 68 | 112 | 159 |
| Weed rating—percent control | | | | | | | |
| Annual grasses | | 0 | 50 | 19 | 25 | | |
| Broadleaved weeds | | 0 | 0 | 32 | 40 | | |

*Cole crops were in the early vegetative stage of growth at the time of harvest. Stands and weights of all crops are the average for 5 feet of row harvested. Planted July 1, 1957; Treated July 2; Harvested August 8.

firm those obtained in the logarithmic sprayer plots and indicate that 1 pound of CDEC in combination with 0.5 pound of CIPC may prove to be a practical pre-emergence treatment for control of annual grasses, chickweed *(Stellaria media)* and henbit *(Lamium amplexicaule)* in these crops.

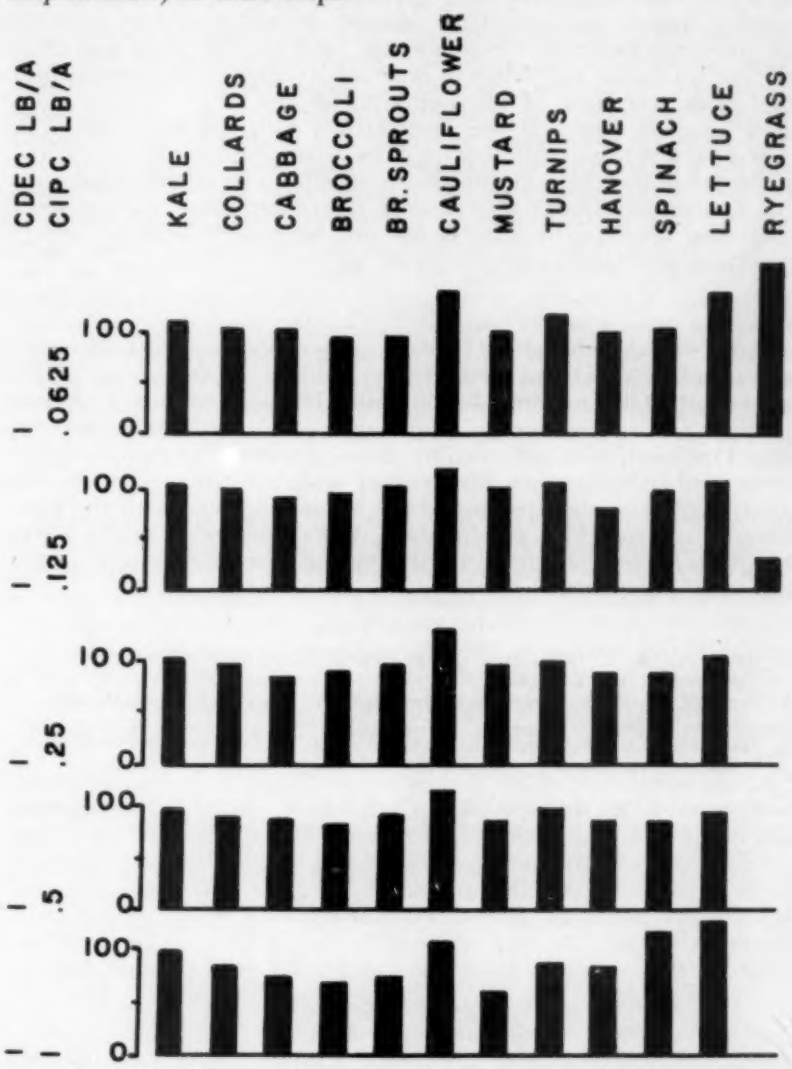


*Figure 4.* Results of the pre-emergence logarithmic sprayer application of 1 pound of CIPC per acre followed by an overall application of 1 pound of CDEC per acre on a series of vegetable greens, salad, and cole crops are shown expressed in terms of a phytotoxicity index for each crop at each treatment level range sampled. See Table 2 for range of rates over 1 yard of row sampled. A phytotoxicity index of 100 indicates normal growth and an index of 0 indicates complete kill. Planting and treatment date April 22, 1957. Harvest date May 31, 1957.

*General evaluation of the logarithmic sprayer*

Results obtained in these investigations indicate that the logarithmic sprayer is a useful tool for the field evaluation of herbicides. The time and space required to carry out field evaluations on a series of vegetable crops were greatly reduced by the use of this sprayer. Some indication of the amount of time saved may be given by citing the fact that it was possible for 2 men to plant and treat the equivalent of 1200 plots in one day. Averages of the results of 4 replicates were used to determine quickly the range of rates tolerated by each crop and the weed killing range of each chemical. These results were then used in subsequent randomized replicated plots to confirm the optimum levels of application determined with the logarithmic sprayer. The data presented here show that the weed and crop response to a herbicide can be quickly and accurately determined by this combination of methods.

## SUMMARY

A logarithmic, or variable-dosage, sprayer was used in field evaluations of herbicides on vegetable greens, salad, and cole crops. EPTC alone and CDEC in combination with CIPC were studied to obtain preliminary information on crop response and herbicidal effectiveness. Optimum rates indicated by these logarithmic rate applications were used in subsequent randomized replicated plots. A statistical analysis of these data confirmed the results obtained with the logarithmic sprayer. This combination of methods of evaluation was found to be very effective in reducing the time and space required for such experiments.

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# Effects of DCB, DCB-xylene Mixtures, Amitrol, and Sodium Salt of Dalapon in Irrigation Water on Corn and Rutabagas[1]

V. F. Bruns and J. H. Dawson[2]

In tests conducted at Prosser, Washington, during 1955 and 1956, DCB (orthodichlorobenzene), alone or in combination with xylene, showed considerable promise for controlling submersed aquatic weeds when introduced into irrigation channels. The first objective of the experiment reported herein was to determine whether irrigation water treated with DCB or DCB-xylene mixtures would injure certain crop plants. In other tests amitrol (3–amino–1,2,4–triazole) and sodium salt of dalapon (sodium 2,2–dichloropropionate) were effective in controlling certain emergent aquatic and ditchbank weeds. Frequently, the application of herbicides to control such weeds results in inadvertent or unavoidable contamination of water used to irrigate crop plants. Consequently, a second objective of this investigation was to determine the approximate quantities of amitrol and sodium salt of dalapon required to injure certain crop plants when applied in irrigation water, and to study the symptoms of injury.

## Review of Literature

Bruns, et al. (7) reported that irrigation water containing xylol or similar aromatic solvents at concentrations and rates found necessary to control the most resistant submersed aquatic weeds caused no economically important injury to alfalfa, Red Mexican beans, carrots, cotton, grain sorghum, Ladino white clover, lettuce, lima beans, oats, orchard grass, potatoes, sugar beets, or sweet corn. No literature on the effects of DCB in irrigation water on crop plants was found.

Several workers have demonstrated that soil applications of amitrol and sodium salt of dalapon may damage various crop plants through absorption by the root systems (4, 9, 11, 12). Amitrol evidently is inactivated rapidly in most soils (2, 3). Reports of damage to weeds and crop plants from soil applications of this material have been inconsistent. Whether lack of injury to certain crops planted after applications of amitrol was a result of leaching, bacterial action, chemical breakdown, adsorption by the soil, or a combination of these has not been determined (1). However, *in vitro* experiments by Ercegovich (8) have shown that the rate of disappearance of amitrol from treated Hagerstown silt loam is influenced by temperature, pH, and moisture.

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Holstun and Loomis (10) reported that sodium salt of dalapon was very mobile and leached readily from several soil types. Little of this compound was adsorbed by any of three silty clays or silt loams. Thus, sodium salt of dalapon apparently can be carried freely into the root zone in soil solution. Soil micro-organisms reportedly decompose sodium salt of dalapon (10, 13), but this process may require several weeks. Therefore, the presence of either amitrol or sodium salt of dalapon in irrigation water conceivably could endanger farm crops.

## MATERIALS AND METHODS

The present studies were conducted on Sagemoor very fine sandy loam. This soil is low in organic matter and has a depth of 60 inches to bedrock.

After application of 600 pounds of ammonium nitrate (33 percent nitrogen) per acre on May 27, 1957, the land was plowed, harrowed, ditched, and irrigated. On June 4, the experimental area was disked, harrowed, and cultipacked. Then 33 plots (11 plots within 3 blocks), each 10 x 20 feet, were laid out on contour with a zero grade. The alleyways between the blocks were 10 feet wide and the borders of adjacent plots were at least 4 feet apart. Four rows of 85-day corn (*Zea mays* L.) (Wisconsin 240), 24 inches apart and 10 feet long, were planted on one half of each plot on June 5. Damage by pheasants necessitated replanting on June 12. On July 5, the corn was thinned to average 1 plant per 9 inches of row (approximately 15,680 plants per acre).

After preparation of a seedbed by hand-cultivation, four rows of rutabagas (American Purple Top), 24 inches apart and 10 feet long, were seeded on the other half of each plot on August 1. On August 22, the rutabagas were thinned to average 1 plant per 3 to 4 inches of row (approximately 41,000 plants per acre).

Six 600-gallon tanks, equipped with valves, hoses, and boom attachments, were used throughout the experiment for applying irrigation water and chemicals. This technique has been described in earlier publications (5, 6). All plots received regular irrigations before and after chemical treatment. The irrigation furrows were dammed at each end of the plots and the flow of water from the tanks was regulated and adjusted to maintain a given level of water in the furrows. Thus, the problem of measuring runoff water and discarding the effluent was eliminated. Normal field cultivation was simulated by the use of hand tools.

Eleven different plot treatments were randomized within each of the three blocks. These treatments included one rate of DCB (740 parts per million), three DCB-xylene mixtures (each at 740 parts per million in ratios of 1:9, 1:3, and 1:1), three rates of amitrol (0.25, 1.25, and 2.5 pounds per acre), three rates of sodium salt of dalapon (0.5, 2.5, and 5.0 pounds per acre), all in 3 acre-inches of irrigation water, and no treatment (check). The measured dosages of amitrol and sodium salt of dalapon dissolved readily when added to the appropriate quantities of irrigation water in the tanks. Measured dosages of DCB and DCB-xylene, however, were first mixed thor-

oughly with an oil-water emulsifier. These mixtures were then added to a 1-gallon jug of water. These 1-gallon formulations were introduced under pressure into the supply of irrigation water in the tanks by means of a knapsack sprayer. The spray nozzle was submersed and the water was agitated with a wooden paddle during the introductions. This procedure created satisfactory and sufficiently stable emulsions.

The concentration of 740 parts per million of DCB and DCB-xylene mixtures was chosen to correspond to the upper range in concentrations of similar materials commonly used for the control of aquatic weeds in irrigation channels. In previous experiments on cattails, 8 pounds of amitrol per acre and 15 pounds of sodium salt of dalapon per acre gave comparable control of these emergent aquatic weeds. Therefore, in attempting to select rates which would result in injury as well as no injury to the test crops, lower dosages of amitrol than of sodium salt of dalapon were used.

The sub-plots of corn were treated on July 10–12, when the plants were in the 5- to 7-leaf stage of growth. The sub-plots of rutabagas were treated when the plants were in the 6- or 7-leaf stage of development (September 9-11). During chemical treatments, the irrigation furrows were dammed between sub-plots as well as at the ends of the main plots.

On September 18, the corn on each plot was cut, bundled, and shocked. On October 31, the dried shock corn was weighed, the number of ears was recorded, and the corn was shelled. Yields of shelled corn were determined on an oven-dry basis and converted to bushels per acre on the basis of 15.5 percent moisture content.

The rutabagas were harvested, graded, and weighed on October 28. Rutabagas measuring 2 inches or more in diameter were arbitrarily classified as No. 1, whereas those between 1 and 2 inches were classified as No. 2. Smaller rutabagas were discarded.

## RESULTS AND DISCUSSION

### *Corn*

Within 3 days after treatment, the DCB and DCB-xylene mixtures caused severe wilting of the corn leaves. Some leaves turned dark or became desiccated, or both. Crowns and crown roots were damaged. During the next 2 weeks, growth was inhibited markedly and many plants continued to deteriorate (Figure 1).

Growth of corn on plots treated with sodium salt of dalapon at the rates of 2.5 and 5.0 pounds per acre was suppressed. Terminal leaves crinkled, especially near the bases or collars. Apparently, these leaves failed to unfold while the stalk continued to elongate, and a definite curvature and an extremely compact roll resulted (Figure 2). Spotted interveinal necrosis developed on the last open and uncurled leaves. These symptoms developed rapidly after the first regular irrigation following the chemical treatments. As the season advanced, the heavier rates of sodium salt of dalapon continued to suppress the growth and to cause malformation of the stalks. Nearly all stalks produced small or abortive ears. The ears were severely malformed and few or no kernels developed (Figure 3).

*Figure 1.* Top: Untreated check. Bottom: Effects of 740 ppm of DCB applied in 3 acre-inches of irrigation water when corn was in the 5- to 7-leaf stage.

*Figure 2.* Typical malformation caused by applications of sodium salt of dalapon at both 2.5 and 5.0 pounds per acre in 3 acre-inches of irrigation water to corn in the 5- to 7-leaf stage. Note the curved and extremely compact roll of the terminal leaves.

Whether the cover of the ears consisted of foliar leaves as well as husks was difficult to determine. Separation of the small ears or cobs from this intergrown mass of leaves was nearly impossible.

No injury was detected on plots treated with sodium salt of dalapon at the rate of 0.5 pound per acre. No visible symptoms of chemical injury in the foliage or other damage was observed on plots treated with amitrol. In fact, the general condition of corn on plots treated with amitrol, including color and vigor, appeared somewhat superior to the condition of corn on untreated check plots. Weed competition was not a factor because the plots were hand-weeded. These observations compare favorably with results obtained by Ercegovich (8) who took a series of samples of corn planted in soil treated with amitrol throughout the growing season. Chemical analysis of the samples failed to reveal any measurable residue of amitrol in the corn tissue at any time.

All DCB and DCB-xylene mixtures caused significant reduction in yields of shock and shelled corn and number of ears (Table 1). Likewise, sodium salt of dalapon at 2.5 and 5.0 pounds per acre caused significant decreases in yields. Only 0.4 bushel of shelled corn per acre was produced on plots treated with sodium salt of dalapon at the 5.0-pound rate. Sodium salt of dalapon at 0.5 pound per acre and the amitrol treatments caused no reduction in yields.

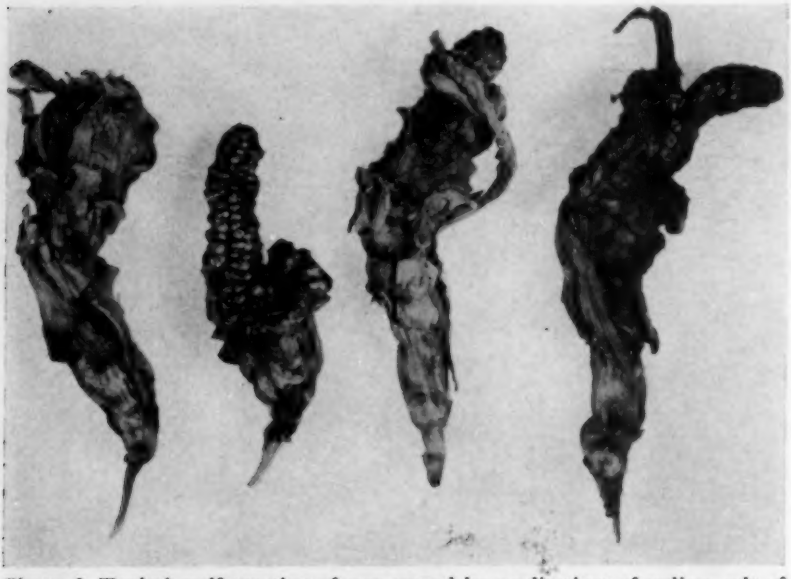

*Figure 3.* Typical malformation of ears caused by applications of sodium salt of dalapon at both 2.5 and 5.0 pounds per acre in 3 acre-inches of irrigation water to corn in the 5- to 7-leaf stage.

*Table 1.* Effects on yields per acre (Oct. 31, 1957) of herbicides applied in irrigation water (3 acre-inches) on July 10–12 to corn in the 5- and 7-leaf stage.

| Chemical and dosage | Shock corn, tons | Ears, number | Shelled corn @ 15.5% moisture, bushels |
|---|---|---|---|
| DCB: | | | |
| 740 ppm | 3.40** | 16880** | 26.0** |
| DCB-xylene mixtures: | | | |
| 740 ppm, 1:9* | 7.98** | 28314** | 71.1* |
| 740 ppm, 1:3 | 6.67** | 26136** | 63.1* |
| 740 ppm, 1:1 | 6.37** | 27225** | 49.9* |
| Amitrol: | | | |
| 0.25 lb/A | 11.76 | 40838 | 95.4 |
| 1.25 lb/A | 14.10 | 44105 | 109.1 |
| 2.5 lb/A | 14.92 | 47916 | 118.3 |
| Dalapon, sodium salt: | | | |
| 0.5 lb/A | 13.07 | 38660 | 108.5 |
| 2.5 lb/A | 8.79** | 31581* | 29.1** |
| 5.0 lb/A | 4.90** | 15791** | 0.4** |
| None (untreated check) | 13.23 | 44649 | 102.7 |
| LSD 5% | 3.16 | 10346 | 31.0 |
| 1% | 4.33 | 14157 | 42.2 |
| Coef. of variation, percent | 19.4 | 18.2 | 25.8 |

*DCB:xylene ratio by volume.
* Difference from check exceeds the 5 percent level of probability.
**Difference from check exceeds the 1 percent level of probability.

## *Rutabagas*

Within 1 week after the applications, rutabagas on plots treated with DCB and the 1:3 mixture of DCB-xylene began to wilt and

become prostrate. At that time, none of the other treatments had caused visible injury.

As the season progressed, the growth of rutabagas on plots treated with DCB and the 1:3 mixture of DCB-xylene was suppressed noticeably. Plants on plots treated with the 1:1 mixture of DCB-xylene tended to lack normal vigor. The only injury noted on plots treated with amitrol was slight discoloration of some of the leaves which came into direct contact with treated water during the application. Sodium salt of dalapon, especially at the heavier rates, caused a slight change in the appearance of the foliage. The leaves tended to be slightly more crinkled and somewhat lacking in vigor and luster.

Neither the total number of rutabagas nor the number of those between 1 and 2 inches in diameter was reduced significantly by any treatment (Table 2). Only DCB and the 1:3 and 1:1 mixtures of DCB-xylene caused significant reductions in the number of rutabagas measuring 2 inches or more in diameter.

*Table 2.* Effects on yields (Oct. 28, 1957) of herbicides applied in irrigation water (3 acre-inches) on Sept. 9–11 to rutabagas in the 6- or 7-leaf stage.

| Chemical and dosage | Number per plot (80 sq ft) | | | Tons per acre |
|---|---|---|---|---|
| | 1- to 2-inch diameter | More than 2-inch diameter | Total | |
| DCB: | | | | |
| 740 ppm | 50 | 5** | 55 | 1.87** |
| DCB-xylene mixtures: | | | | |
| 740 ppm, 1:9* | 46 | 40 | 86 | 6.27 |
| 740 ppm, 1:3 | 47 | 17** | 64 | 3.40** |
| 740 ppm, 1:1 | 56 | 21* | 77 | 4.47 |
| Amitrol: | | | | |
| 0.25 lb/A | 42 | 38 | 80 | 5.40 |
| 1.25 lb/A | 42 | 41 | 83 | 6.51 |
| 2.5 lb/A | 39 | 46 | 85 | 6.05 |
| Dalapon, sodium salt: | | | | |
| 0.5 lb/A | 45 | 39 | 84 | 5.91 |
| 2.5 lb/A | 40 | 36 | 76 | 5.20 |
| 5.0 lb/A | 43 | 39 | 82 | 6.13 |
| None (untreated check) | 44 | 38 | 82 | 5.81 |
| LSD 5% | NS | 14 | NS | 1.67 |
| 1% | | 20 | | 2.28 |
| Coef. of variation, percent | | 25.5 | | 18.3 |

*DCB:xylene ratio by volume.
* Difference from check exceeds the 5 percent level of probability.
**Difference from check exceeds the 1 percent level of probability.

The total yield in tons per acre was reduced by DCB and the 1:3 mixture of DCB-xylene only. Although the yield from plots treated with the 1:1 mixture of DCB-xylene averaged 1.34 tons per acre less than that from untreated checks, the difference was not statistically significant.

The results from this experiment show that water treated with DCB or DCB-xylene mixtures for aquatic weed control in irrigation channels should not be used to irrigate crop plants. At the rates tested, sodium salt of dalapon in irrigation water appeared more hazardous to certain crop plants, particularly corn, than amitrol. It should be pointed out that contamination of irrigation water from appli-

cations of sodium salt of dalapon for the control of cattails or ditchbank weeds in or along irrigation channels or reservoirs seldom would exceed the equivalent of 0.5 pound per acre in 3 acre-inches of water, a concentration which caused no significant injury to corn or rutabagas in this experiment.

## SUMMARY

When applied to corn in the 5- to 7-leaf stage and rutabagas in the 6- or 7-leaf stage of growth, DCB and 1:3 and 1:1 mixtures of DCB-xylene at 740 parts per million in 3 acre-inches of irrigation water caused injury. The 1:9 mixture of DCB-xylene also caused injury to corn.

Applied at the same stages of growth, sodium salt of dalapon at 2.5 and 5.0 pounds per acre in 3 acre-inches of irrigation water caused severe injury to corn but only slight injury to rutabagas. Sodium salt of dalapon at 0.5 pound and amitrol at 0.25, 1.25, and 2.5 pounds per acre caused no significant damage to either corn or rutabagas.

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# A Three-Year Study of the Effect of Some Phenoxy Herbicides on Cotton

W. K. Porter, Jr., C. H. Thomas, and J. B. Baker[1]

The chlorinated phenoxyalkylcarboxylic acids are extremely valuable in affording a solution to many weed problems. On the other hand, the use of such herbicides may create problems since many crop or ornamental plants which are very sensitive to the phenoxy herbicides may be growing in close proximity to crops or areas in which treatments with such herbicides seems desirable. In the South, cotton may be planted adjacent to crops such as rice, sugarcane or corn or in areas bordering woods, highways or railways. On such areas, the application of phenoxy herbicides may solve the problem of weed control; however, they may create a new problem by causing injury to cotton.

As early as 1948, Brown et al. (2) reported that 2,4–D (2,4–dichlorophenoxyacetic acid) drift was causing serious injury to cotton in Louisiana. Their preliminary results indicated that plants injured during the flowering period were likely to show yield reductions. Similarly, in 1949, Ergle et al. (3) reported some response of cotton to 2,4–D. Both of the above groups described certain typical symptoms which developed as a result of 2,4–D injury. McIlrath (6) presented evidence that leaf malformation similar to those caused by 2,4–D could be produced by high dosages of certain phosphate insecticides. Similarly, Normand[2] at this station showed that when high amounts of monuron were placed in the vascular elements of cotton, typical leaf strap malformation occurred.

Watson (8) found that cotton in the early bloom and mid-bloom stage of growth was more susceptible to phenoxy herbicides than at the eight leaf stage. Goodman (1) and Goodman et al. (5) showed that cotton exposed to 2,4–D appeared to be more sensitive at the seedling and square stages than at flowering and boll stages, but in 1952 the flowering stage was about as susceptible as the square stage. Behrens et al. (1) reported that under unfavorable growing conditions herbicide treatments made during the early part of the growing season resulted in the greatest reduction in cotton yield while treatments applied later had a progressively less effect on cotton production.

A number of workers (1, 5, 8) have shown that 2,4,5–T (2,4,5–trichlorophenoxyacetic acid) and Silvex [2–(2,4,5–trichlorophenoxy) propionic acid] were less injurious to cotton than 2,4–D. According to their observations, the degree of injury may be related to varying environmental conditions.

McIlrath et al. (7) reported that under certain conditions the 2,4–D stimulus may be transferred to the cotton seed.

During the years that the phenoxy herbicides have been used, numerous questions have arisen in relation to their toxicity to

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[2]Private communication, 1954.

cotton. These questions generally center around two main points: (1) At what stage of growth is cotton most sensitive (as measured by yield reduction) to phenoxy herbicides? (2) Is cotton equally sensitive to different members of the chlorinated phenoxyalkylcarboxylic acids? The experiments discussed in this paper were conducted in an attempt to gain information on the above questions.

## METHODS AND MATERIALS

The experiments reported in this study were conducted during the summers of 1955, 1956, and 1957. In 1955, the test location was the Mathis Property and in 1956, 1957, the Essen Lane farm. Both locations are south of Baton Rouge, Louisiana, and the soil is Lintonia silt loam.

In the 1955 experiments the plot size was 1 row by 50 feet and each treatment replicated three times. During 1956 and 1957 the plots were 2 rows by 65 feet, with three replications. In all years the plots were fertilized with 500 pounds per acre of 8–8–8. The cotton variety used was DPL–15. Insect control was practiced as necessary throughout the season.

The herbicides used in this study were the alkanolamine salt of 2,4–D,[3] triethylamine salt of 2,4,5–T and alkanolamine salt of silvex. In 1955 the rates used were 0.0, 0.001, 0.01 and 0.1 lb/A. During 1956 and 1957 rates of 0.0, 0.0001, 0.001 and 0.01 lb/A were used.

The herbicides were applied to cotton at four stages of growth: cotyledonary, 8–10 leaf, 1st square and 1st boll. The herbicides were applied at dawn when the wind velocity was near zero so as to avoid drift of the herbicide to adjacent plots. Application was from tractor mounted pressure tanks operating at 30 psi. A separate tank was used for each different herbicide and the lower rate treatments were always applied first. A single nozzle centered over each row and delivering a volume of spray equivalent to 40 gal/A was used.

The plots were hand harvested in 1955 and machine harvested in 1956 and 1957. All yield data were converted to pounds of seed cotton per acre.

## RESULTS AND DISCUSSION

The rapidity with which phenoxy injury appeared in cotton was highly dependent upon the rate of growth of the plant. All of the compounds used in this study caused petiole curvatures on the younger leaves. This petiole curvature was short lived in the case of 2,4–D and 2,4,5–T; however, it persisted several days in silvex treated plants. None of the herbicides caused appreciable malformation on leaves which were mature at the time of application. Figure 1 shows a normal cotton plant on the upper left and a cotton plant treated with 0.0001 lb/A 2,4–D on the upper right. Leaves emerging after treatment showed malformation. 2,4,5–T caused leaf malformation very similar to 2,4–D; however, the quantity of herbicide required to cause the same degree of injury was much greater in the case of 2,4,5–T. Figure 1 shows a healthy plant on the lower left

[3]The authors wish to thank Dr. A. J. Watson, The Dow Chemical Company, Greenville, Mississippi, for furnishing the chemicals used in these studies.

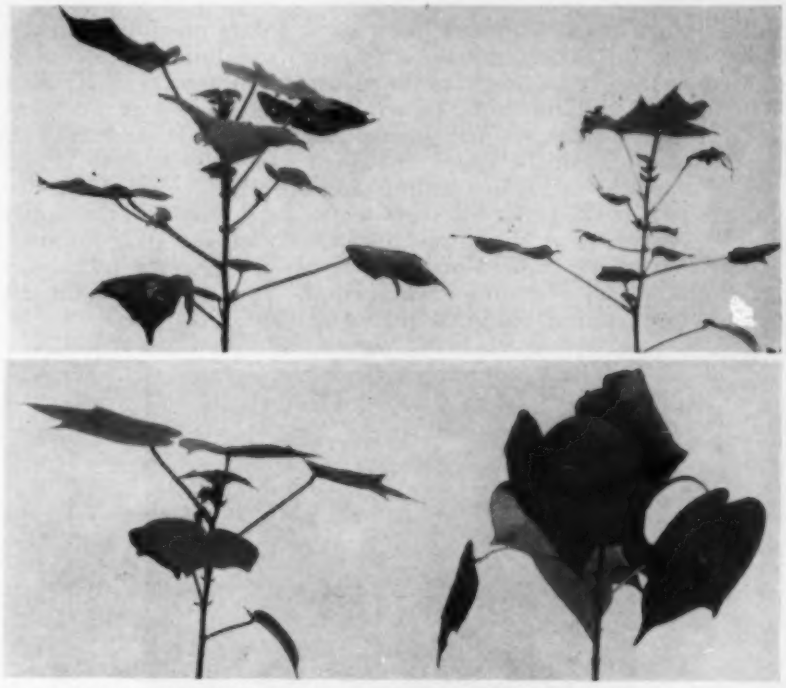

*Figure 1.* Upper left: Healthy plant. Upper right: 2,4–D injured plant. Lower left: Healthy plant. Lower right: Silvex injured plant.

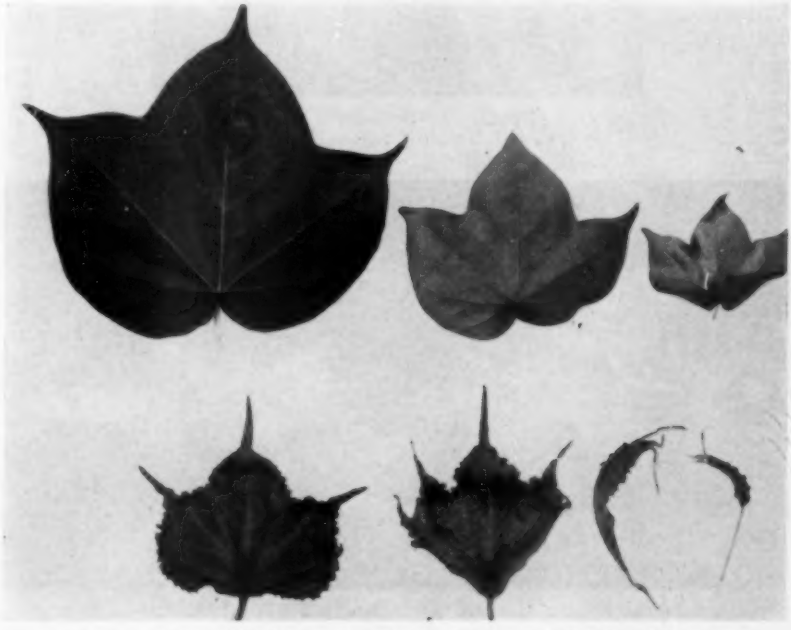

*Figure 2.* Upper: Healthy cotton leaves. Lower: 2,4–D injured leaves.

and a plant treated with 0.01 lb/A silvex 5 days previously on the lower right. Silvex did not cause leaf strap malformations, but it did reduce the overall height of the plant, and in some cases, released a number of axillary buds. Generally, silvex treated plants were more "bushy" than normal plants, whereas 2,4–D and 2,4,5–T treated plants might be called "scrawny."

The types of leaf malformation caused by 2,4–D or 2,4,5–T are shown in Figure 2. The lower set of leaves are injured and the upper set of leaves are from healthy plants and of a growth stage approximately that of the injured ones. In the lower right, the leaf shows maximum injury symptoms, whereas, the leaf on the lower left exhibits only minor marginal malformation.

*Figure 3.* Upper: 2,4–D injured cotton squares. Lower: Healthy cotton squares.

*Figure 4.* Left: Healthy flower. Right: 2,4–D injured flower.

2,4–D and 2,4,5–T also caused square (Figure 3, upper) and flower (Figure 4, right) malformations. In general, squares of flowers injured by the above herbicides are shed.

Of course, the most important influence of the herbicide injury to cotton is on the yield. In Figure 5 it may be seen that an increase in the rate of any of these herbicides caused a decrease in yield. The most injurious compound was 2,4–D, followed by 2,4,5–T and silvex. Silvex appeared to be slightly less injurious than 2,4,5–T. If the average of the three years is considered, it appears that it required from 10 to 100 times more 2,4,5–T and silvex (in the range of rates employed) to cause the same degree of injury as a given rate of 2,4–D. At higher rates this minor selectivity disappeared.

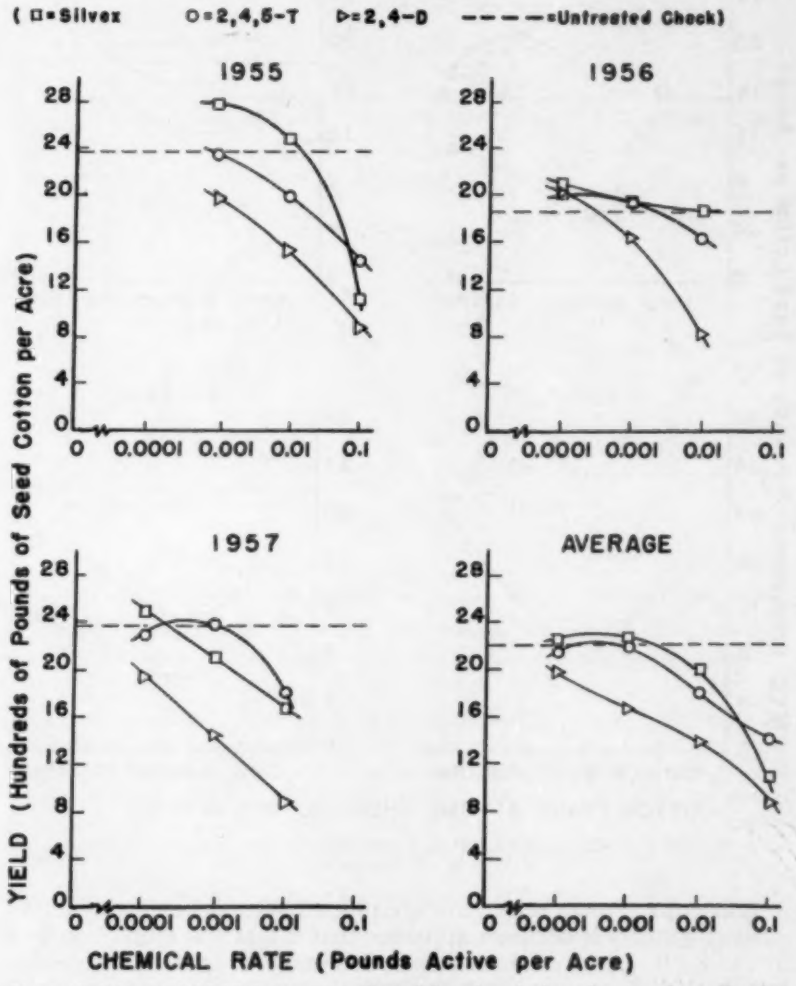


*Figure 5.* Mean yield of cotton as affected by chemical and rate of application over all growth stages.

In Figure 6 it is also quite evident that as the amount of herbicide increased, the yield decreased. At the higher rates, treatments at the 8–10 leaf stage generally reduced yields more than treatments at any other stage. The cotyledonary and 1st square stage appeared to be affected to about the same degree while the 1st boll stage was the least influenced.

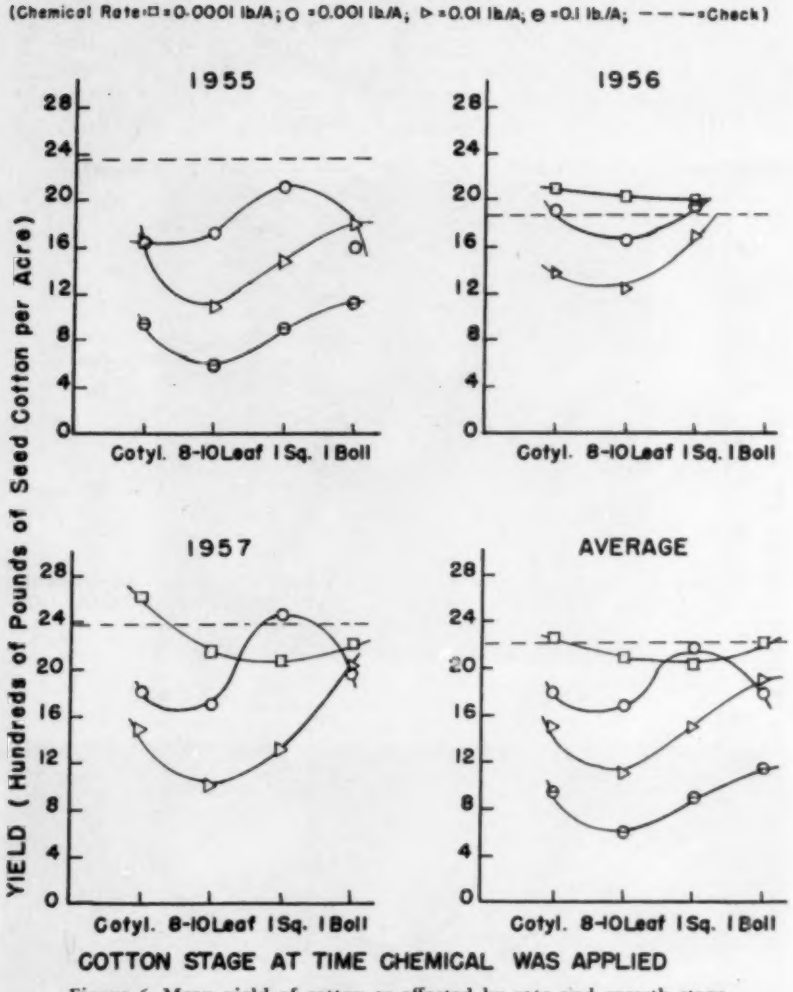


*Figure 6.* Mean yield of cotton as affected by rate and growth stage over all chemicals.

When the growth stage data are plotted versus chemicals over all rates (Figure 7) it becomes apparent that 2,4–D was more injurious at the 8–10 leaf stage than at an other stage of growth. The other two herbicides appear to have had the same influence on yields regardless of the stage of growth at application time.

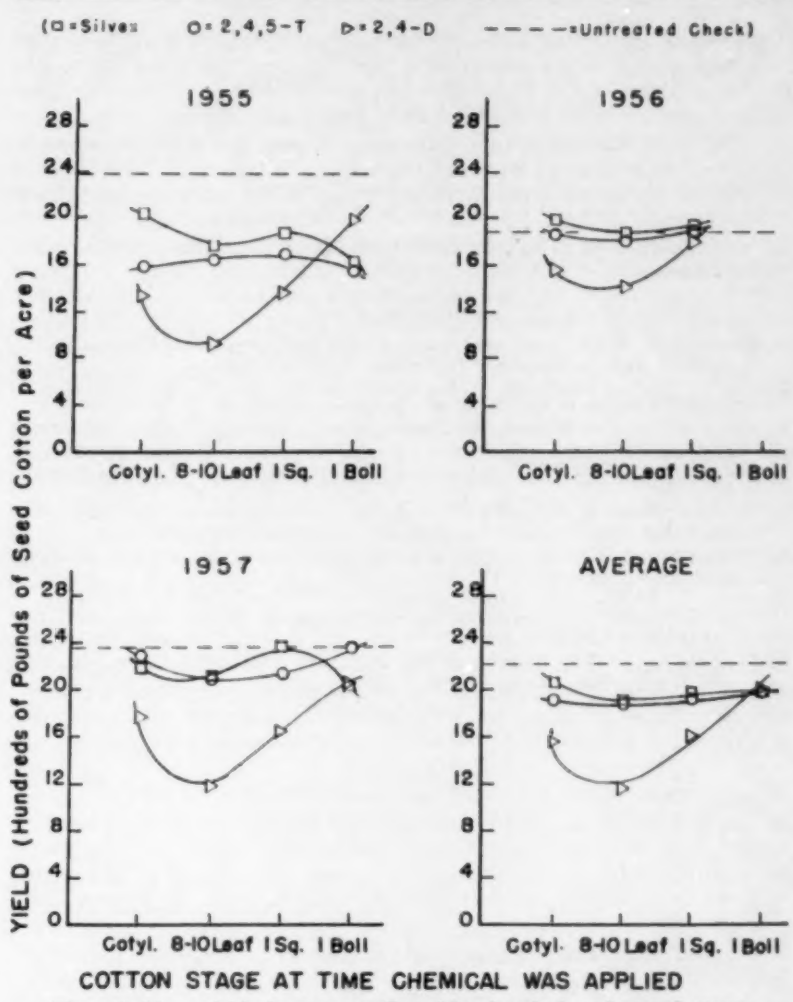


*Figure 7.* Mean yield of cotton as affected by chemicals and growth stages over all rates.

Statements have been made from time to time that 2,4–D may be applied at low dosages in order to increase yields of cotton. In these studies there was only one instance where any rate of 2,4–D was superior to the untreated check (0.0001 lb. rate in 1956), and this increase was non-significant. Certain rates of the other herbicides apparently caused some yield increases, but they were not significant.

## CONCLUSIONS

1. Both 2,4–D and 2,4,5–T caused leaf strap malformation; silvex did not.
2. As the rates of phenoxy herbicides were increased the yield of cotton decreased.

3. At the rates tested 2,4–D caused the greatest yield reduction in cotton, and silvex caused the least. In general, from 10 to 100 times more 2,4,5–T or silvex was required to cause the same amount of yield reduction as a given amount of 2,4–D.
4. The 8–10 leaf stage of cotton growth was the most sensitive to 2,4–D as measured by yield reductions. Silvex and 2,4,5–T were rather nonspecific in yield reduction as far as stage of growth was concerned.
5. Rates of 2,4–D as low as 0.0001 lb/A did not stimulate the yield of cotton.

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# Substituted Urea Herbicides: Their Electrophoretic Behavior and the Influence of Clay Colloid in Nutrient Solution on Their Phytotoxicity[1]

C. W. Coggins, Jr.[2] and A. S. Crafts[3]

Interest in the substituted urea compounds for their herbicidal properties was precipitated by Bucha and Todd's (3) report that 3–(p–chlorophenyl)–1,1–dimethylurea (monuron) was extremely phytotoxic. Freed (6) reported that only asymmetrically substituted ureas are effective as herbicides. Substitution on the *para* position was reported to result in greatest activity followed by *meta*. An *ortho* substitution reduced activity to half or less than that of the comparable *para* substitution.

Wessels and Van Der Veen (16) reported that photosynthesis in monuron-sprayed plants was immediately inhibited and suggested that the herbicide is adsorbed to an active site which is essential for photosynthesis. They also studied the effects of a number of substituted ureas on the Hill reaction and the results were compared to those obtained with phenylurethane. They concluded that replacement of the ethoxy group in phenylurethane by the dimethylamino group and the introduction of a chlorine atom, or a nitro or trifluromethyl group into the aromatic nucleus resulted in an enhanced inhibitory action on the Hill reaction. In contrast to Freed's (6) report, substitution of a chlorine atom or a hydroxyl group in the *meta* position was reported to be more effective than a *para* substitution. The compounds studied were assumed to be adsorbed to the active cyclopentanone ring of chlorophyll by way of hydrogen bonding.

The toxicity of nitrophenylureas to Black Valentine beans *(Phaseolus vulgaris)* was reported by Anderson et al. (1) to be altered by changing the N-alkyl substitution. The dimethyl derivative was most phytotoxic. Lengthening the chain from one to two carbons or removing the alkyl groups reduced the activity.

Moreland and Davis (12) studied the response of an amylase enzyme to five substituted ureas. Maximum inhibition of enzymatic activity was correlated with low water solubility. The authors suggested the possibility that several herbicide molecules, grouped together to form particles of colloidal dimensions, are adsorbed on the enzyme in such a way that its structural configuration is altered and its activity consequently hindered.

Sheets and Crafts (14) studied the toxicity of four substituted ureas to oats *(Avena sativa)* grown in soil or in nutrient solution. They concluded that a shift in the electron balance, caused by the electrophilic chlorine atom, has a profound effect on adsorption of the herbicide on soil colloids. N-alkyl substitutions were considered to

[1]This paper is adapted from a Ph.D. thesis presented by the senior author to the Graduate Division, University of California, 1957.

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alter adsorption to soil colloids without changing the reactivity with cellular constituents. Substituents on the aromatic nucleus were considered to be the parts of the molecules most directly involved in the reactivity of the compounds with cellular constituents.

The amount of monuron adsorbed to twelve different soils was determined by Sherburne and Freed (15). Their results indicate that there is a very high degree of adsorption of monuron on organic matter and a significant amount on clay particles. According to Hill,[4] adsorption of monuron on soils was found to increase when either clay and/or organic matter increased. Hill also reported that much more monuron was adsorbed to a bentonite clay than to kaolinite. A number of workers, Loustalot, Muzik, and Cruzado (10), Day, Russell, and McCarty (5), Gangstad, Seale, and Joyner (7), Dallyn (4), Ries and Sweet (13), and Linder (9), have reported results of field and greenhouse experiments which indicate that adsorption of monuron to clay or organic matter occurs.

The objectives of the biological investigation reported here were: (1) to determine the relative toxicity of five substituted ureas[5] to barley; (2) to correlate phytotoxicity with structure; (3) to evaluate the influence of clay on phytotoxicity; and (4) to determine if clay-herbicide interactions exist.

Paper electrophoretic studies were conducted (1) to determine the sign of the net charge on the substituted ureas dissolved in water, (2) to determine if movement could be related to adsorption of the substituted ureas to wet cellulose, and (3) to study the influence of pH on migration rate.

## MATERIALS AND METHODS

*Biological Studies.*

Barley (*Hordeum vulgare* variety Sacramento or Atlas 44) was seeded in steam-sterilized sand and was subirrigated with water. After 6 to 8 days, the sand was carefully washed from roots of the seedlings and the plants were selected for uniformity. For 2 to 3 days prior to treatment, the roots were suspended in a nutrient solution similar to that reported by Hoagland and Arnon (8). Barley roots were then exposed to the treatment media for short intervals. At the end of the treatment the roots were rinsed and resuspended in the original nutrient medium. Forced aeration was found to be of no benefit to growth of barley under the conditions used and was therefore omitted in all the experiments reported here.

Three to four replications were used in a randomized complete-block design with ten plants per treatment. Results from plants exposed to the various treatment media containing no herbicide were regarded as control data.

In Experiment I barley was exposed for 20 hours to 0, 4.0, 8.0, or 16.0 x $10^{-6}$ molar solutions of monuron, 3–phenyl–1,1–dimethylurea

[4]Hill, G. D. Soil factors as related to herbicide action. Presented at Charter Meeting, Weed Society of America, January, 1956, New York, N. Y.

[5]Experimental samples supplied by E. I. duPont de Nemours & Co., Wilmington 98, Delaware.

(fenuron), 3–(3,4–dichlorophenyl)–1,1–dimethylurea (diuron), and 3–(3,4–dichlorophenyl)–1–methylurea (M). Thirteen days after treatment the plants were harvested and fresh shoot weights recorded.

A Wyoming bentonite clay[6] with a cation exchange capacity of 75 milliequivalents per 100 grams of air-dry material was used in Experiment II and subsequent experiments.

This experiment included 1–*n*–butyl–3–(3,4–dichlorophenyl)–1–methylurea (neburon). Air-dry clay was used at the rate of 1 gram per 100 ml of solution. Clay was either omitted or added to nutrient solutions containing no herbicide or containing diuron, monuron, M, neburon, or fenuron at concentrations of 0.25, 0.50, 0.50, 1.00, or 1.50 x $10^{-5}$ molar, respectively. One concentration for all herbicides could not be used since phytotoxicity varied considerably. Two sets of the nutrient-herbicide-clay mixtures were prepared with each herbicide. In one set the liquid was separated 18 hours after mixing by filtering through porcelain filters having a wall thickness of ⅛-inch and a maximum pore size of 1.4 microns radius.

The treatment period was 48 hours. Seventeen days after treatment the plants were harvested and fresh weights of the shoots were recorded.

In Experiment III clay was either absent or present at a concentration of 14 per cent. Monuron, neburon, and fenuron were present at 0.5, 1.0, and 2.0 x $10^{-5}$ molar concentrations, respectively. Barley was exposed to the treatment media for 74 hours and fresh weights of shoots were recorded 22 days later.

The same clay conditions as in Experiment III were used in Experiment IV. Diuron, M, monuron, neburon, and fenuron were present at concentrations of 0.25, 0.50, 0.50, 1.0, and 2.0 x $10^{-5}$ molar, respectively. The treatment interval was 48 hours and plants were harvested 23 days after treatment.

*Electrophoretic Studies.*

A Spinco model R series B electrophoresis cell and a Spinco Duostat power supply were used in studying the electrophoretic behavior of five substituted ureas. Since corrosion of the metal rods occurred at high hydrogen ion concentrations, the rack was omitted. The test compounds were applied to 1-inch strips of Whatman number 3 MM filter paper moistened with buffered solutions. The ends of each strip were connected to wicks consisting of three layers of Whatman number 1 filter paper that dipped into a buffer reservoir containing a platinum electrode (2).

The rates of migration of monuron, fenuron, diuron, M, and neburon were determined at the pH values indicated in Table 1. The same table lists the buffer-electroylte systems used. The compounds were applied to the strips at the top of the inverted "V." Ten microliters of a 0.05 molar solution of each in 95 per cent ethanol was applied as a uniform streak across the width of the paper.

[6]Obtained from Industrial Minerals and Chemical Company, Sixth and Gilman Streets, Berkeley 10, California.

*Table 1.* Buffers used in the electrophoretic experiment.[a]

| pH (10° C.) | Buffer components (stock solutions) | Amount/liter |
|---|---|---|
| 2.0 | 1.0M glycine, 1.0M NaCl | 2.65 ml. |
| | 2.08 M HCl | 3.55 ml. |
| 4.1 | 2.0M sodium acetate | 5.0 ml. |
| | 3.5 M acetic acid | 8.4 ml. |
| 5.0 | 2.0M sodium acetate | 5.0 ml. |
| | 3.5 M acetic acid | 0.93 ml. |
| 6.4 | 0.5 M $Na_2HPO_4$ | 4.15 ml. |
| | 4.0M $NaH_2PO_4$ | 0.93 ml. |
| 7.4 | 0.5M $Na_2HPO_4$ | 6.1 ml. |
| | 4.0M $NaH_2PO_4$ | 0.13 ml. |
| 8.7 | 1.0M glycine, 1.0M NaCl | 8.6 ml. |
| | 2.14 M NaOH | 0.64 ml. |
| 9.4 | 1.0M glycine, 1.0M NaCl | 5.8 ml. |
| | 2.14 M NaOH | 2.0 ml. |
| 10.7 | 1.0M glycine, 1.0M NaCl | 3.8 ml. |
| | 2.14 M NaOH | 3.0 ml. |

[a]Modified from Miller and Golder (11).

A potential of 420 volts was applied for 6 hours. The cell was maintained at 8° to 10° C. during the period of migration and the buffer was 0.01 ionic strength. Following 6 hours of migration the papers were dried and the front was detected by use of a Photovolt model 52-C densitometer equipped with a mercury-arc lamp and a blue sensitive phototube.

## RESULTS AND DISCUSSION

### *Biological studies.*

Inherent phytotoxicity, as used here, refers to the toxicity of the substituted ureas to barley grown in nutrient solutions in the absence of clay. The results presented in Figures 1 through 4 indicate that the five substituted ureas may be arranged in the following order of decreasing phytotoxicity: diuron, M, monuron, neburon, and fenuron.

From a consideration of the relative phytotoxicity and the structural formulae, it appears that the introduction of one or two chlorine atoms enhances phytotoxicity. When the N-alkyl substitution was constant the dichloro compound was more phytotoxic than the monochloro compound. When the phytotoxicity of diuron and M was compared, it appeared that two methyl groups were necessary for maximum phytotoxicity to be expressed. The phytotoxicity of the dichloro series was lowered even more by replacement of one of the methyl groups with a butyl group as found with neburon.

Wessels and Van Der Veen (16) considered that inhibition of the Hill reaction with substituted ureas was related to hydrogen bonding potentials. They assumed that the compounds must be adsorbed to some cellular constituent for the phytotoxic action to be expressed.

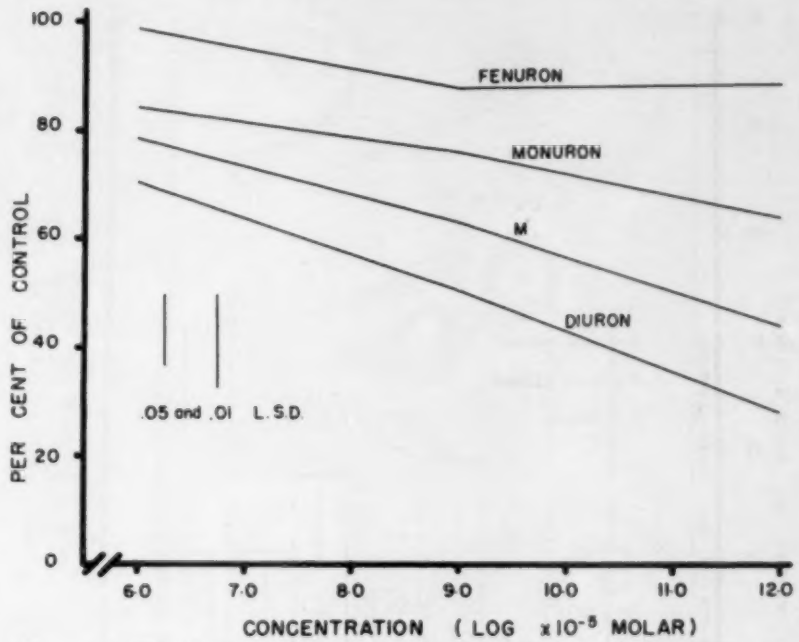


*Figure 1.* Relative fresh weight of barley shoots 13 days after exposure of roots for 20 hours to four substituted ureas.

It is possible that the differences in phytotoxicity of the five substituted ureas used in the present study were determined in part by hydrogen bonding potentials.

Clay at 1 per cent (Fig. 2) appeared to reduce the phytotoxicity of neburon but had little or no influence on the toxicity of the other compounds. Experiment II was repeated with essentially the same results. At a clay concentration of 14 per cent (Figs. 3 and 4) the phytotoxicity of all compounds tested was reduced by clay. The decreasing order of clay influence on phytotoxicity appeared to be M, diuron, neburon, monuron, and fenuron.

The reduction in toxicity of neburon to barley in the presence of 1 per cent bentonite is probably due to adsorption of neburon to the clay. The differences in phytotoxicity between the filtrate and presence of clay during treatment is probably due to some of the neburon being desorbed as the plants adsorbed the herbicide from solution. In addition to desorption the plant may be subjected to some of the adsorbed herbicide by contact exchange when clay is present.

When 14 per cent bentonite was used, neburon appeared to be influenced less than diuron and M. Since only the phytotoxicity of neburon was decreased by 1 per cent bentonite, the sum total of the evidence probably should be interpreted to mean that the influence of clay on phytotoxicity is more pronounced with neburon followed

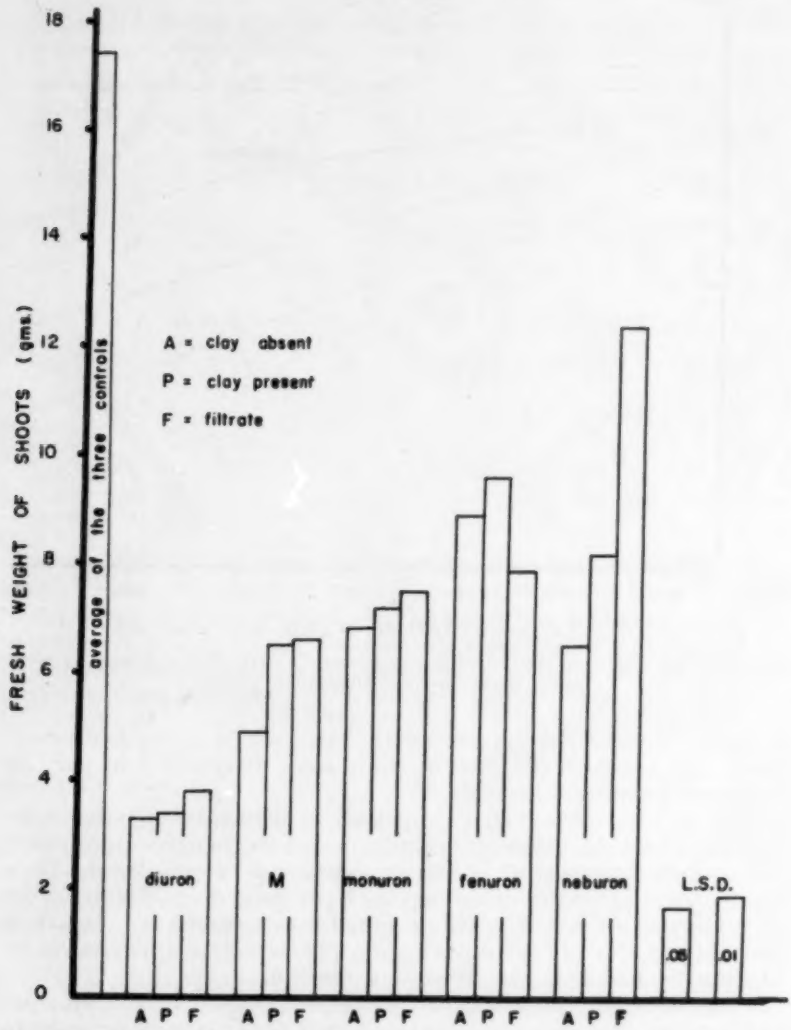


*Figure 2.* Influence of 1 percent bentonite clay on the phytotoxicity of five substituted ureas to barley—Experiment II. Concentrations of the substituted ureas given in Table 1.

by M, diuron, monuron, and fenuron. If adsorption of the substituted ureas to wet cellulose is regulated by the same forces which regulate adsorption to clay, support for the above statement is found in paper electrophoretic experiments reported in this paper.

*Electrophoretic studies.*

Since the materials were applied in amounts which exceeded their solubility in water, they did not move as discrete bands but as streaks.

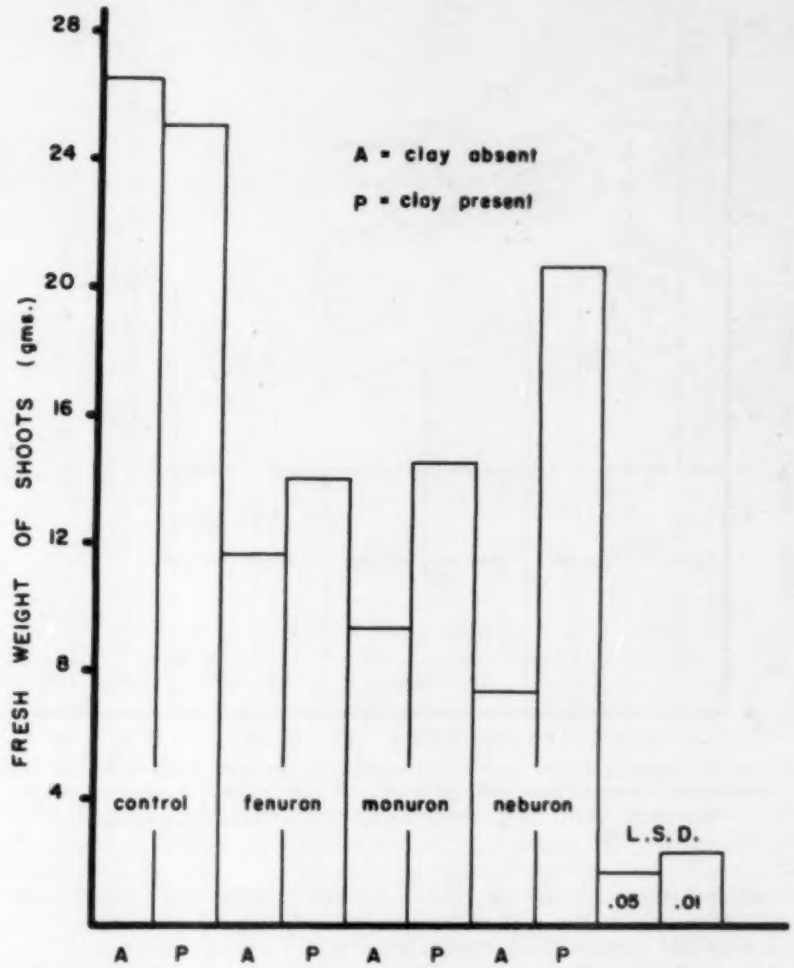


*Figure 3.* Influence of 14 percent bentonite clay on the phytotoxicity of three substituted ureas to barley—Experiment III. Monuron, neburon, and fenuron were present at 0.5, 1.0 and 2.0 x $10^{-5}$ molar concentrations, respectively.

For a considerable distance back of the front, the optical density was high (0.4–0.6) and rather constant until the front was approached closely. Near the front the optical density decreased very rapidly reaching an optical density of 0.1 in a distance of approximately 2 mm. When an optical density of 0.1 was obtained, the paper was marked and the distance from the point of origin was measured. This was defined as the distance migrated. An optical density of 0.1 was selected to be above the variability of the paper. Also a reading of approximately 0.1 would be obtained if the compounds were present on the paper at one-fourth the concentration of a saturated

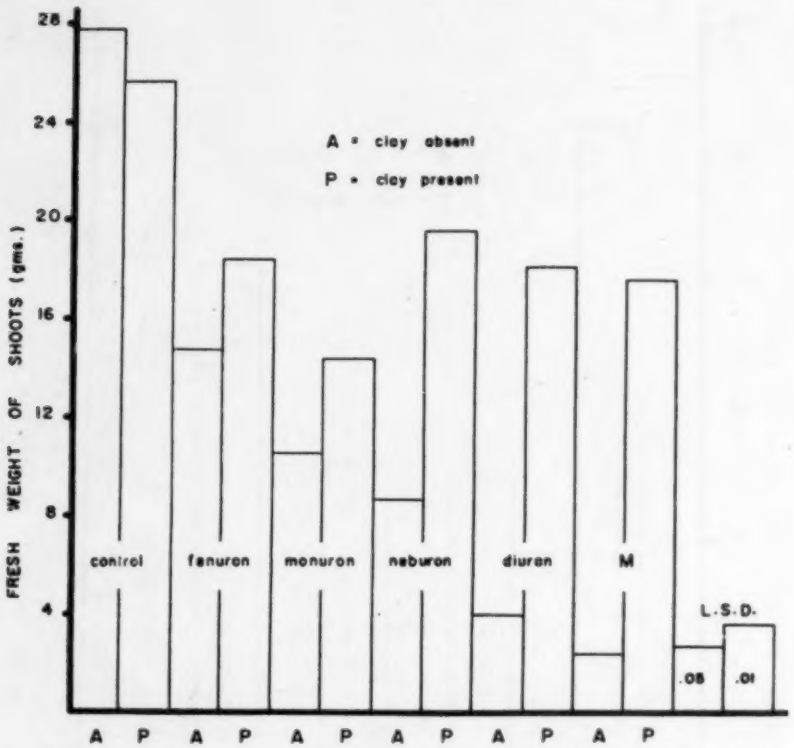


*Figure 4.* Influence of 14 percent bentonite clay on the phytotoxicity of five substituted ureas to barley—Experiment IV. Diuron, M, monuron, neburon, and fenuron were present at concentrations of 0.25, 0.50, 0.50, 1.0 and 2.0 x $10^{-5}$ molar, respectively.

water solution of the least soluble compound (neburon) tested. The distances which the compounds migrated toward the cathode at various pH levels are shown in Figure 5.

Migration rates may be considered to be regulated largely by (1) size and shape of the molecules, (2) net charge on the migrant, and (3) degree of adsorption to paper. Molecular weights of the compounds are known but the relative net charge is an unknown factor. Evidence that different rates of movement may be largely controlled by differential adsorption was obtained by subjecting the compounds to a potential in a system containing 50 per cent methanol. Equal rates of migration occurred suggesting that methanol interfered with absorption of the substituted ureas on cellulose.

Although size, net charge, and other factors should not be completely discounted as differentially influencing the rates of migration of the substituted ureas in the water-buffer system, different degrees of adsorption of the herbicides to the paper is probably the most important factor to be considered. Within any one pH and across

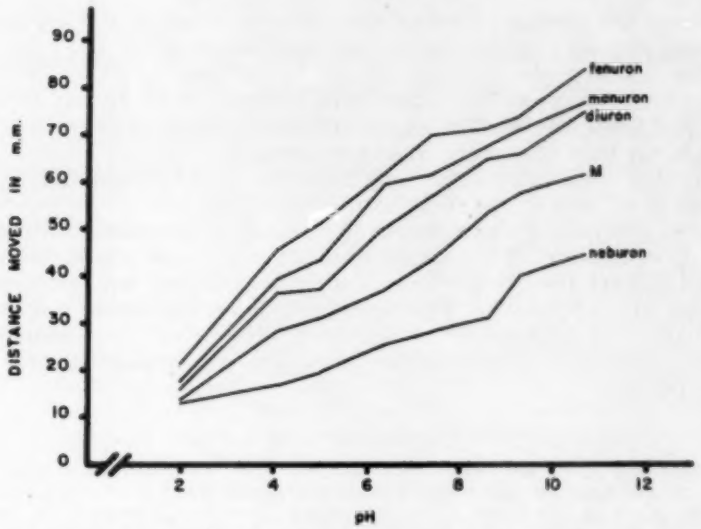


*Figure 5.* Influence of pH on the movement of five substituted ureas in an electric field.

the pH range used, neburon thus appears to be more strongly adsorbed followed by M, diuron, monuron, and fenuron. If the reduction in phytotoxicity caused by a bentonite clay is also due largely to adsorption, one can conclude that the substituted ureas are probably adsorbed to wet cellulose and to wet clay by similar mechanisms.

For any one herbicide an increase in hydrogen ion concentration favored increased adsorption. Since the substituted ureas are basic by virtue of accepting hydrogen ions, the increased hydrogen ion concentration should lead to a larger percentage of the compounds possessing a net charge. If adsorption were not important in determining the rate of migration, increased hydrogen ion concentration should result in faster movement of the compounds.

From pH effects on migration one might conclude that pH should be one variable in soils which influences biological activity of the substituted ureas through its effect on adsorption.

## SUMMARY

Five substituted ureas were found to have the following order of decreasing toxicity to barley when the compounds were exposed to barley roots in nutrient solution: diuron; M; monuron; neburon; and fenuron. Maximum phytotoxicity was associated with the presence of two chlorine atoms in the aromatic nucleus and with two methyl groups on the number one nitrogen atom. Replacement of one of the methyl groups with a hydrogen atom or with a butyl group reduced the phytotoxicity. When the alkyl substitutions were

constant, the incorporation of one chlorine atom in the aromatic nucleus increased phytotoxicity; two increased it more.

Clay reduced the toxicity of the substituted ureas to barley. Neburon was most strongly influenced followed by M, diuron, monuron, and fenuron. The differential influence of clay on phytotoxicity may be in part related to hydrogen bonding.

The five substituted ureas were found by paper electrophoresis to possess a net plus charge in water solutions. The rate of migration of any one compound was found to increase with decreasing hydrogen ion concentration. Throughout the pH range used, fenuron was found to have the greatest rate of migration followed by monuron, diuron, M, and neburon. The rate of migration was considered to be influenced by adsorption of the herbicides to cellulose with the slowest rate of migration corresponding to the greatest degree of adsorption.

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## BRIEF PAPERS

# The Effect of Temperature and Light on Germination of Seed of Goosegrass, *Eleusine indica*[1]

J. R. Fulwider and R. E. Engel[2]

Goosegrass, a widely distributed annual weed, creates difficult problems in heavily used turf areas. The seriousness of this weed problem, especially on golf course greens and tees, has suggested studies for its control. Very little research has been conducted in regard to this grass. Germination studies by Toole and Toole[3] showed that 0.2% potassium nitrate was superior to water when used to moisten the substratum. Their work also indicated exclusion of light had little effect on germination at alternating temperatures of 20°–30°C. The present study includes more complete temperature and light comparisons, and attempts to demonstrate light and temperature effects on seed germination.

## Material and Methods

Goosegrass seed used in this experiment was harvested approximately six months previous to the study and placed in cold dry storage. A 0.2% solution of potassium nitrate ($NKO_3$) was used to moisten the substratum. Four plates of 100 seeds each were subjected to ten different temperature and light conditions (Table 1). The

*Table 1.* Germination of seed of *Eleusine indica* with different temperature and light conditions, average of four tests of 100 seed each.

| Days from start of germination test | Germination (percent) with varied light and temperature combinations | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 15°C. | 20°C. | 30°C. DL[a] | 30°C. | 35°C. DL | 35°C. | 20–30°C. DL | 20–30°C. | 20–35°C. DL | 20–35°C. |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 9.8 | 0.5 | 0 | 0 | 0 | 0 | 25.5 | 8.5 |
| 10 | 0 | 2.0 | 67.0 | 0.3 | 0 | 0.3 | 2.0 | 0.8 | 65.5 | 70.0 |
| 14 | 0 | 0.5 | 14.3 | 0.5 | 0 | 0 | 4.5 | 4.3 | 0.8 | 14.0 |
| 17 | 0 | 0 | 4.0 | 0 | 0 | 0 | 21.0 | 1.5 | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 33 | 0 | 0 | 0.5 | 0 | 0 | 0 | 6.5 | 6.8 | 0 | 0 |
| 40 | 0 | 0 | 0 | 0 | 0 | 0 | 56.3 | 10.0 | 0 | 0 |
| 57 | 0 | 0 | 0 | 0 | 0 | 0 | 1.0 | 1.3 | 0 | 0 |
| 68 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 38.0 | 0.3 | 0 |
| Av. percent | 0 | 2.5 | 95.6 | 1.3 | 0 | 0.3 | 91.3 | 62.7 | 92.1 | 92.5 |

[a]DL = Alternating light and dark.

temperature and light conditions used include 15°C., 20°C., 30°C., 35°C., 30°C.DL, 35°C.DL, 20–30°C., 20–35°C., 20–35°C.DL, and

[1]Paper of the Journal Series, New Jersey Agr. Exp. Sta., Rutgers—the State University, New Brunswick, New Jersey.

[2]Formerly research assistant and associate research specialist, Farm Crops Department, Rutgers, respectively. Special acknowledgement is made to Mr. Robert Hess for his cooperation and use of the Federal Seed Laboratory facilities, where these studies were conducted.

[3]Toole, E. H. and Toole, V. K. Germination of seed of goosegrass, *Eleusine indica*. Jour. Amer. Soc. Agron. 32:320–321. 1940.

20–35°C. A single numeral indicates a constant temperature; two numerals separated by a dash indicate an alternation of temperatures in which the test was held at the first temperature for approximately 16 hours. The symbol DL indicates light was provided for the 16 hour period. No symbol indicates the test was held in a dark germinator. The germinators used were so constructed as to maintain high humidity conditions and renewal of the moistening agent was not necessary.

Counts of germinating seeds were made at intervals of three or four days for the first 14 days and at 7 days for the next 43 days. Only the seedlings which appeared healthy and normal were counted as germinated.

## RESULTS AND DISCUSSION

Conditions of 20–30°C.DL, 20–35°C.DL, 20–35°C., and 30°C.DL gave very good germination. The percentage germination values obtained were grouped within the narrow range of 91 to 96 percent as shown by Table 1.

Treatments of 15°C. and 20°C. failed to produce appreciable germination. No germination occurred at a constant temperature of 35°C. with or without light.

Light was an important factor for good germination at 30°C. where maximum germination percentages were obtained with alternating light and dark. Germination with complete darkness was poor at the same temperature. Under conditions of continuous darkness, the only appreciable germination obtained was fair germination at 20–30°C., and good germination at 20–35°C. Germination was also delayed more at the 20–30C. temperature than at the 20–35°C. temperature.

Since light was more important to 20–30°C. temperature than 20–35°C. and germination tended to be more rapid at the 20–35°C. temperature, the optimum maximum germinating temperature appears to be somewhere between 30°C. and 35°C. Under conditions of alternating temperatures of 20–35°C. with and without light, the importance of light seems to be compensated by ideal temperatures.

Goosegrass has been known to appear in startling abundance in turf areas where the grass cover has been destroyed suddenly. Improved germination of goosegrass with light and higher temperatures offers a theoretical explanation for such occurrences.

## SUMMARY AND CONCLUSIONS

Goosegrass seed was harvested six months prior to germination tests and placed in cold dry storage. Replicated lots of the seed were placed on substratums that had been moistened with a 0.2% solution of potassium nitrate and subjected to varied treatments of light, alternating temperatures, and low to high germinating temperatures. A summary of results and conclusions follow:

1. Temperature and light conditions of 30°C.DL, 20–30°C.DL, 20–35°C. and 20–35°C.DL, gave goosegrass germination of 90% or more.

2. Light was essential for good germination of goosegrass at the constant temperature of 30°C., and aided germination at the 20–30°C. condition. Light was less important at the higher temperatures of 20–35°C.

3. The rapidity of germination was increased by the presence of light at alternating temperatures of 20–30°C. and 20–35°C.

4. Optimum germination of goosegrass was influenced by a combination of factors. Light, alternating temperatures, and comparatively high germinating temperatures aid good germination.

# The Persistence of 4–(2–methyl–4–chlorophenoxy)butyric acid in Peas

H. A. Glastonbury, Margaret D. Stevenson and R. W. E. Ball[1]

The possible use of the phenoxybutyric acids as selective herbicides in the pea crop has been recognized from the beginning of their development (3) and preliminary experiments with the more important compounds of this series carried out in 1954 indicated that 4–(2–methyl–4–chlorophenoxy)butyric acid [4–(MCPB) showed the most promise (1). To date no results have been reported on the persistence of MCPB in peas; experiments were, therefore, undertaken to determine this under field conditions.

Part of a crop of Onward peas at the 3 to 4 leaf stage was sprayed June 17, 1958 with a commercial formulation of the sodium salt of MCPB, using a small plot sprayer, at a rate of 2 lb/A. A sample was cut immediately after spraying (Experiment A). Thirty minutes after spraying rain fell and continued to fall intermittently for a period of six hours. Another area of the same field was, therefore, sprayed at the same rate the next morning under ideal conditions (Experiment B).

There was some distortion of the pea plants in both plots which became evident on the day after spraying. Recovery was good, however, and apart from a slight yellowing of the foliage, growth was normal by the tenth day. By the fourteenth day the leaves had largely regained their normal colour.

Samples, which were gathered immediately after spraying (zero time) and then at convenient intervals, were cut at ground level and consisted of four short lengths of row taken at random from the plots. The samples were placed in polythene bags, weighed, and taken to the laboratory within an hour of cutting. The samples were dried, extracted with sodium hydroxide, the proteins were precipitated with phosphotungstic acid and the free MCPB was isolated by solvent extraction and estimated by infra-red spectroscopy. Quantitative results were obtained from this non-quantitative procedure by isotope dilution analysis using MCPB labelled in the carboxyl group with $C^{14}$. The analytical method, which has a limiting sensitivity of 1 ppm calculated on the fresh weight of plant material, has been described in detail by Glastonbury and Stevenson (2). Growth dilution was corrected for, using a factor calculated from the weight of plant per unit length of row at the time of sampling.

The results of these experiments are plotted in Fig. 1, which shows the variation of MCPB content with time in each experiment. The daily rainfall in inches over the period is indicated in the figure. The maximum temperatures at Ongar, 5 miles from the plots, on June 17th and 18th were 83° and 65° F. respectively, the minimums 54° and 40°. The average maximum for June 17 to July 2 inclusive was 71°, the average minimum 50°.

[1]Physical chemist, physical chemist, and agronomist, respectively, the Research Laboratories of Messrs. May & Baker Ltd., Dagenham, Essex, England.

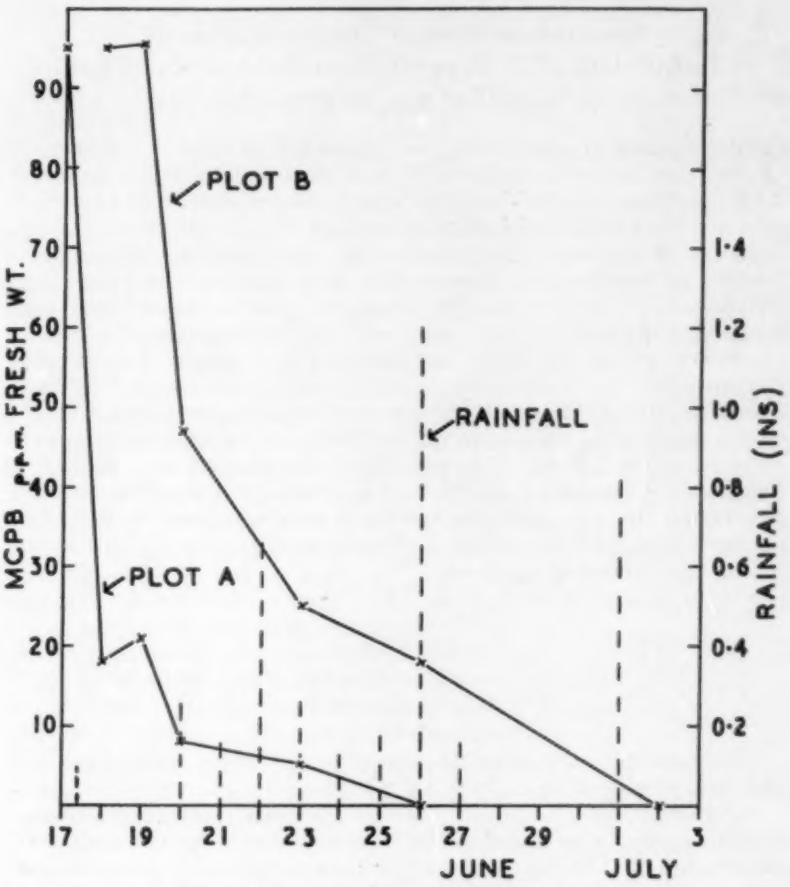


*Figure 1.* The persistence of MCPB in peas.

The effect of rainfall immediately after spraying is shown by a comparison of the two experiments: in experiment A, where rain fell 30 minutes after spraying, the MCPB content decreased by about 80% over the first day while in experiment B, where no rain fell over the first 24 hours, the MCPB content remained constant over that period. Penetration, however, appears to have been fairly rapid and the half-life of retained chemical was of the order of 3 days and was not influenced by further rainfall.

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# Spectrofluorometric Determination of 1:1′–Ethylene–2:2′–Bipyridylium Dibromide (FB/2)[1]

V. H. Freed and Robert E. Hughes, Jr.[2]

The herbicidal and desiccant properties of 1:1′–ethylene–2:2′–bipyridylium dibromide have been reported by Brian et al. (1). This substance appears to be a rapid acting translocated herbicide, effective on a wide range of plant species (1,2).

In the course of investigations with this material, it became of interest to measure its concentration in solution in the ppm range. Brian et al. (1) had reported an absorption maximum of 308–311 mμ for the compound and this fact with the obvious possibilities for resonance in the molecule suggested that it might fluoresce (3). Accordingly, the fluorescent behavior of a solution of FB/2 was examined in an Aminco-Bowman spectrofluorometer. It was found that a fluorescent maximum occurred at 342 mμ with an activating wave length of 310 mμ. The procedure was adapted to a method of quantitative estimation of FB/2 upon finding the fluorescent intensity varied linearly with concentration over the range of 0.1 to 6.0 μg per ml. A plot of intensity versus concentration yielded a plot fitting the following equation:

$$y = \frac{x}{(0.258 \pm .016)} + b$$

where y = concentration of FB.2 in ppm
x = fluorescent intensity
b = a constant

The boundary conditions imposed in this experiment were such that $b = 0$ at $y = 0$.

At higher concentrations (up to 20 ppm) spectrophotometric determination was found to be more satisfactory, measuring the absorbance at 310 mμ. Still higher concentrations (up to 60 ppm) were most satisfactorily measured by treating a 5.0 ml portion of solution with 2.0 ml of 20% NaOH, diluting to 10 ml and measuring the color intensity at 420 mμ.

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[1]Contribution from the Agricultural Chemistry Department, Oregon Agricultural Experiment Station, Corvallis, Oregon.

[2]Agricultural Chemistry Department, Agricultural Experiment Station, Oregon State College, Corvallis, Oregon.

## Sustaining Members

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Thompson-Hayward Chemical Company, Kansas City, Missouri
United States Borax & Chemical Corp., Los Angeles, California

## News and Notes

P. A. Castelfranco was recently employed by the Department of Botany, University of California, where he will be in charge of research on the action and fate of herbicides in plants. He recently received the Ph.D. in agricultural biochemistry at Berkeley after having done his undergraduate work at the same institution.

D. E. Bayer has been appointed as an extension weed specialist in the Department of Botany, University of California, Davis, where he will be associated with W. A. Harvey. Bayer recently completed work for the Ph.D. at the Department of Agronomy, University of Wisconsin, and was formerly associated with Oregon State College, Corvallis.

Harold Kempen, who completed his undergraduate work at the University of Wisconsin, is now employed by the Department of Botany, University of California, with headquarters at the USDA Cotton Field Station, Schafter, California. He is assisting J. H. Miller (ARS) in a cooperative program of weed control in cotton.

Neal E. Shafer recently resigned his position in weed research with the Department of Agronomy, University of Nebraska and is now employed by Cyanamid International Division of American Cyanamid Company. His headquarters is in New York. He is concerned with development of agricultural chemicals throughout the world.

Clyde C. Dowler began work on the agronomic aspects of witchweed control and eradication at the Border Belt Tobacco Research Station, Whiteville, North Carolina, on April 1. He is in the Plant Control Division, ARS, USDA. He received the Ph.D. degree in 1958 at The Ohio State University.

# BIBLIOGRAPHY OF WEED INVESTIGATIONS
## for
## October, November, December, 1958

## Table of Contents


| | *Reference Number* |
|---|---|
| I. Economic Aspects and General Weed Problems | 1 |
| II. Botany of Weeds | |
| A. Classification and Identification | 28 |
| B. Ecological Investigations and Surveys | 39 |
| C. Physiological Investigations | 49 |
| D. Morphological and Anatomical Investigations | 75 |
| E. Weed Seed Investigations | 76 |
| III. Weed Control | |
| A. Cultural | — |
| B. Chemical | |
| 1. Weeds in field crops | 78 |
| 2. Weeds in horticultural crops | 100 |
| 3. Weeds in grasslands, including grass-legume pastures, rangeland, turf, lawns, and cemeteries | 137 |
| 4. Weeds in specialized areas, including ditchbanks, canal ditches, fencerows, rights-of-way, irrigation ditches, and cities | 149 |
| 5. Woody plants | 161 |
| 6. Aquatic weeds | 173 |
| 7. Specific weeds | 179 |
| C. Biological | 207 |
| IV. Chemical and Biochemical Investigations | 208 |
| V. Special Characteristics of Weeds | |
| A. Poisonous Plants and Their Control | 223 |
| B. Uses of Weeds | — |
| C. Pathological and Entomological Relationships | — |
| VI. Nature and Properties of Chemicals Used as Herbicides | 245 |
| VII. Effect of Herbicides on Soils, Livestock, and Humans | — |
| VIII. Equipment, Methods of Application, and Herbicidal Calculations | 275 |
| IX. Legal Aspects | 286 |



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UNITED STATES DEPARTMENT OF AGRICULTURE

Agricultural Research Service

Crops Research Division


This bibliography of current literature on weeds and their control is issued as a service to those engaged in weed research in the United States and other countries. In issuing this bibliography the Crops Research Division, Agricultural Research Service, U.S.D.A. does not assume responsibility for the subject matter cited.


Beltsville, Maryland

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